

# Research Methods in Computing

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# How have we been learning Research Methods [1]

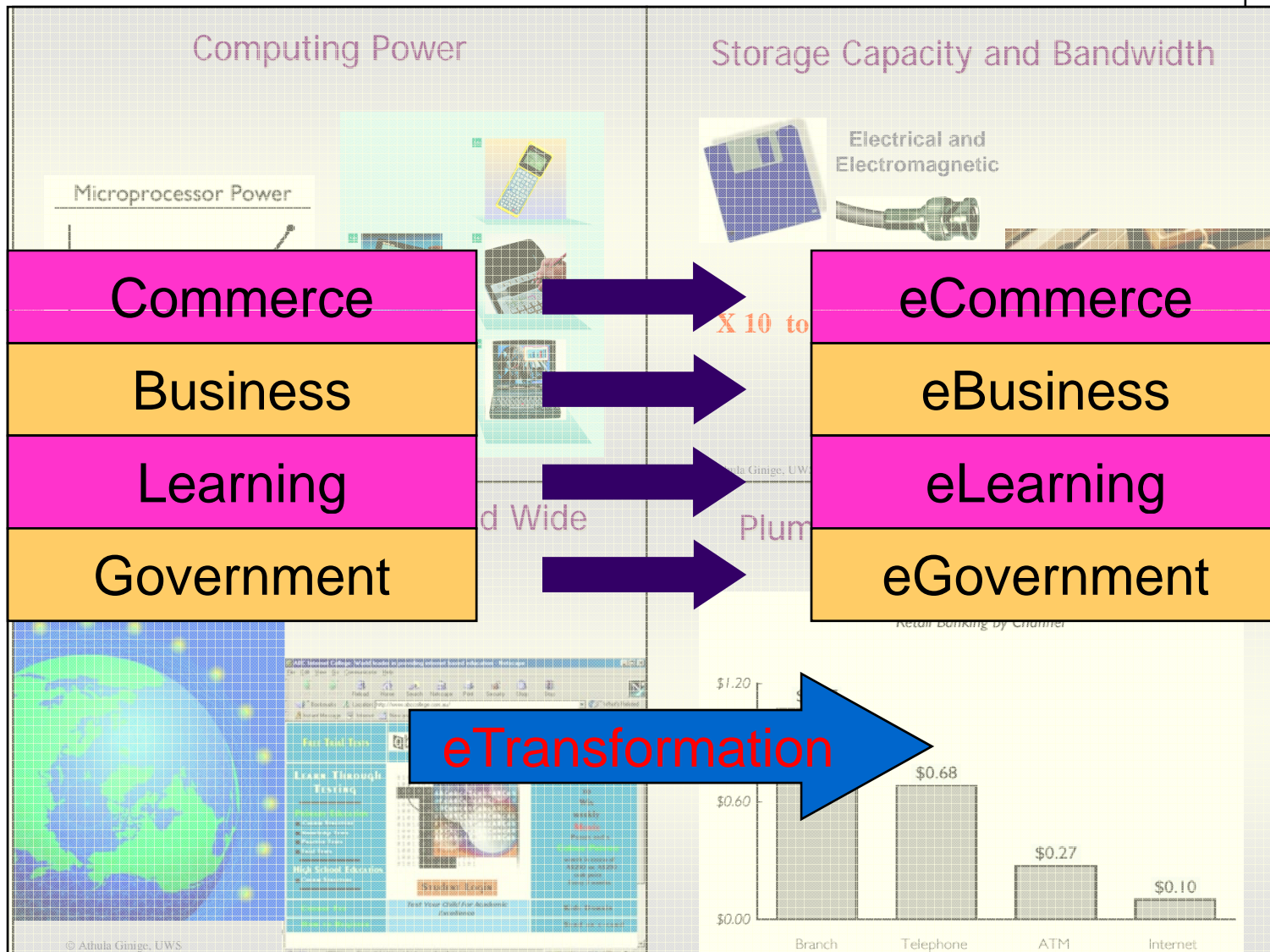


- In computer science, research methods have historically been passed from advisor to student via apprenticeship [101, 105].
- Most of us learned these methods from a mentor or not at all.

[101] K. Ward. The fifty-four day thesis proposal: first experiences with a research course. *J. Comp. Sci. Colleges*, 20(2), 2004.

[105] I. Witten and T. Bell. Getting research students started: a tale of two courses. In *SIGCSE '93*, Indianapolis, IN, March 1993, 165-169.

# Diversity of Computing Research



# Social Transformation

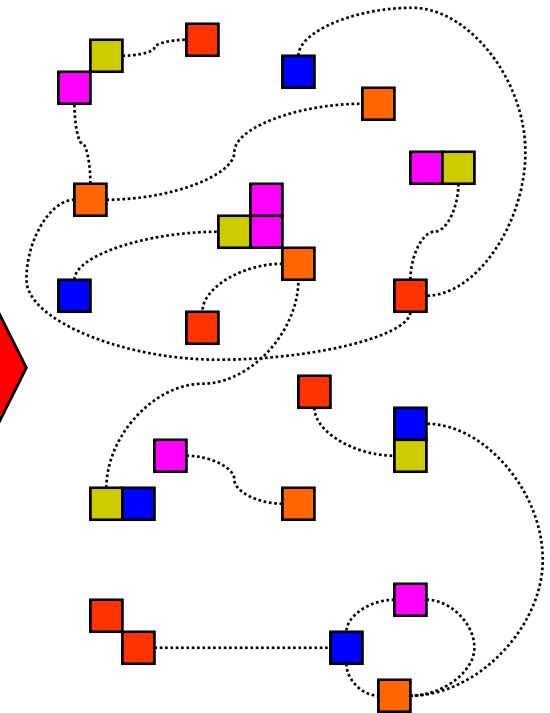
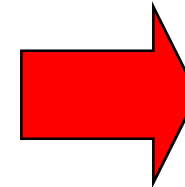
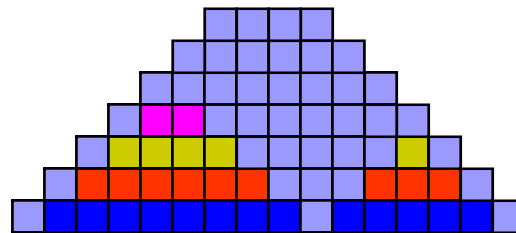
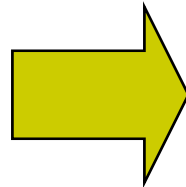
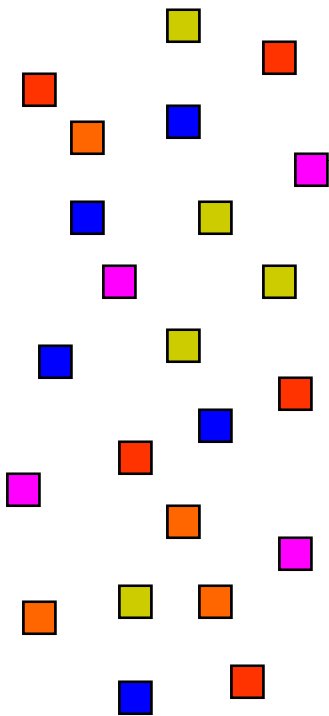


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1850

1970

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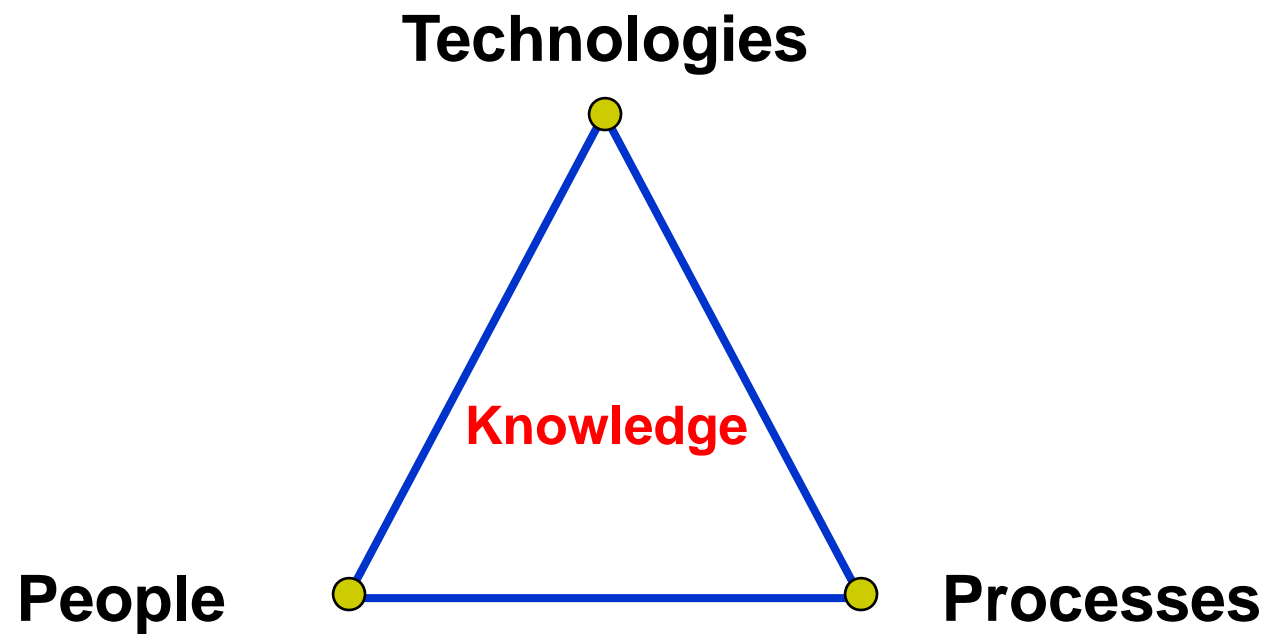


**Agricultural Society**

**Industrial Society**

**Information Society**

# Research Topics in Computing



# References



1. H. J. Holz, A. Applin, B. Haberman, D. Joyce, H. Purchase, and C. Reed, "Research methods in computing: what are they, and how should we teach them? ," presented at ITiCSE on Innovation and technology in computer science education Bologna, Italy 2006.
2. <http://www.socialresearchmethods.net/kb/index.php>
3. [http://en.wikipedia.org/wiki/Main\\_Page](http://en.wikipedia.org/wiki/Main_Page)
4. <http://www.geocities.com/Athens/3238/page3-15.htm>
5. Computing Curricula 2005, ACM, 30 September 2005
6. R.L. Glass, V. Ramesh, and I. Vessey. An analysis of research in computing disciplines. Commun. ACM, 47(6):89–94, June 2004.

# Workshop Structure



- Session 1: Introduction
- Session 2: Some specific Research Methods
- Session 3: Research Methods for Participants' Research questions
- Session 4: Case Studies

# Session 1: Introduction



- Introductions
  - Participants and research activities
  - Specific Research Questions
- A broader view of research
- How to find a research question
- Scope of Computing Research



# Introductions



- Participants and research activities
- Specific Research Questions

# What is Research



- Research encompasses activities that increase the sum of human knowledge [OECD Definition].
- Research is generation of New Knowledge

# What is Knowledge [3]



**Knowledge** is defined ([Oxford English Dictionary](#)) variously as

- expertise, and skills acquired by a person through [experience](#) or [education](#); the theoretical or practical understanding of a subject,
- what is known in a particular field or in total; facts and information or
- awareness or familiarity gained by experience of a fact or situation.
- Philosophical debates in general start with Plato's formulation of knowledge as "[justified true belief](#)". There is however no single agreed definition of knowledge presently, nor any prospect of one, and there remain numerous competing theories.

# What is Research – working Defn. [4]



- Research is a **process** through which we attempt to achieve systematically and with the support of data
  - the answer to a question,
  - the resolution of a problem,
  - or a greater understanding of a phenomenon.
- **This process**, which is frequently called *research methodology*, has eight distinct characteristics:
  - Research originates with a question or problem.
  - Research requires a clear articulation of a goal.
  - Research follows a specific plan or a procedure.
  - Research usually divides the principal problem into more manageable sub-problems.
  - Research is guided by the specific research problem, question, or hypothesis.
  - Research accepts certain critical assumptions.
  - Research requires the collection and interpretation of data in attempting to resolve the problem that initiated the research.
  - Research is, by its nature, cyclical; or more exactly, helical.

# Research should be repeatable



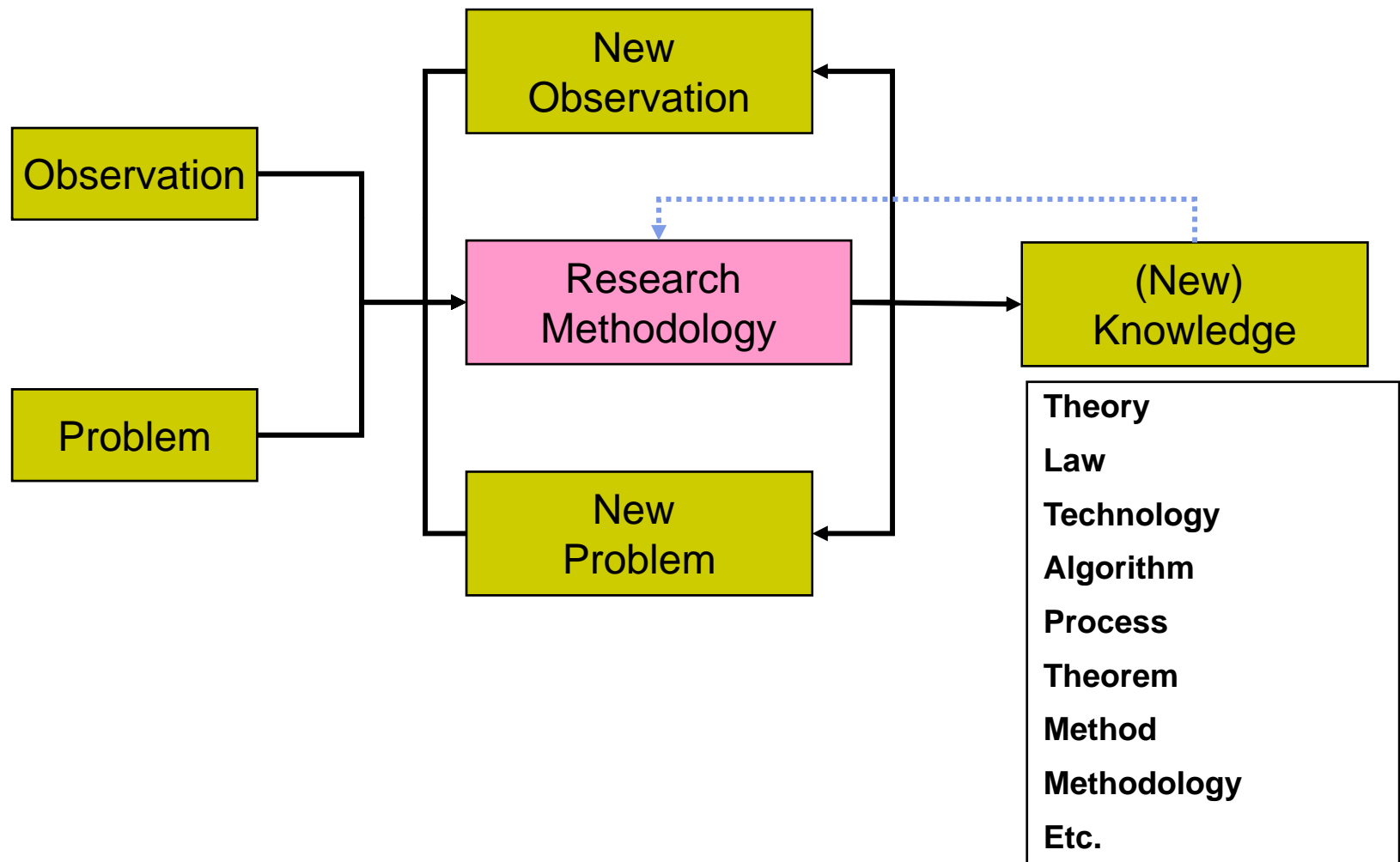
- Research is a systematic process that consists of specific activities. – Research Methodology
- It should produce new Knowledge. – Justified True Belief
- If the result is true then every time we conduct the process we should get the same result independent of the people (Community of Practitioners – CoP) performing the process.

# Implications



- When reporting research findings we need to describe the process in sufficient details for someone else to conduct the process and validate the findings.
- How do we decide on a suitable research methodology?
- How do we conduct different activities (Research Methods) that form the research methodology?

# Process to generate New Knowledge



# Where do research topics come from?

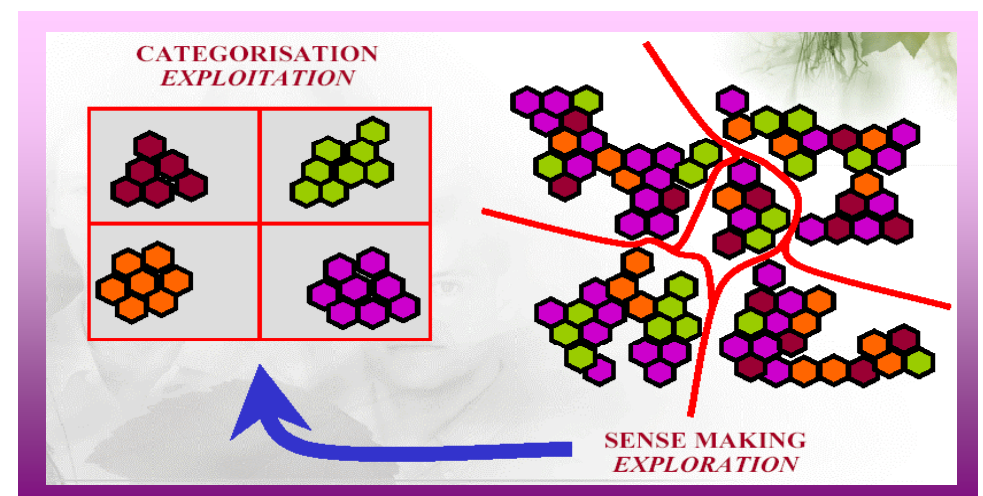
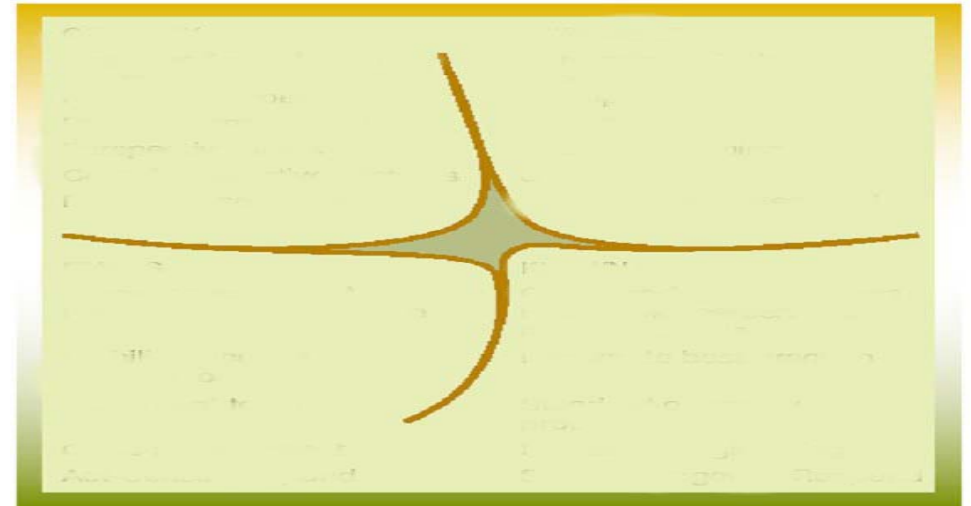
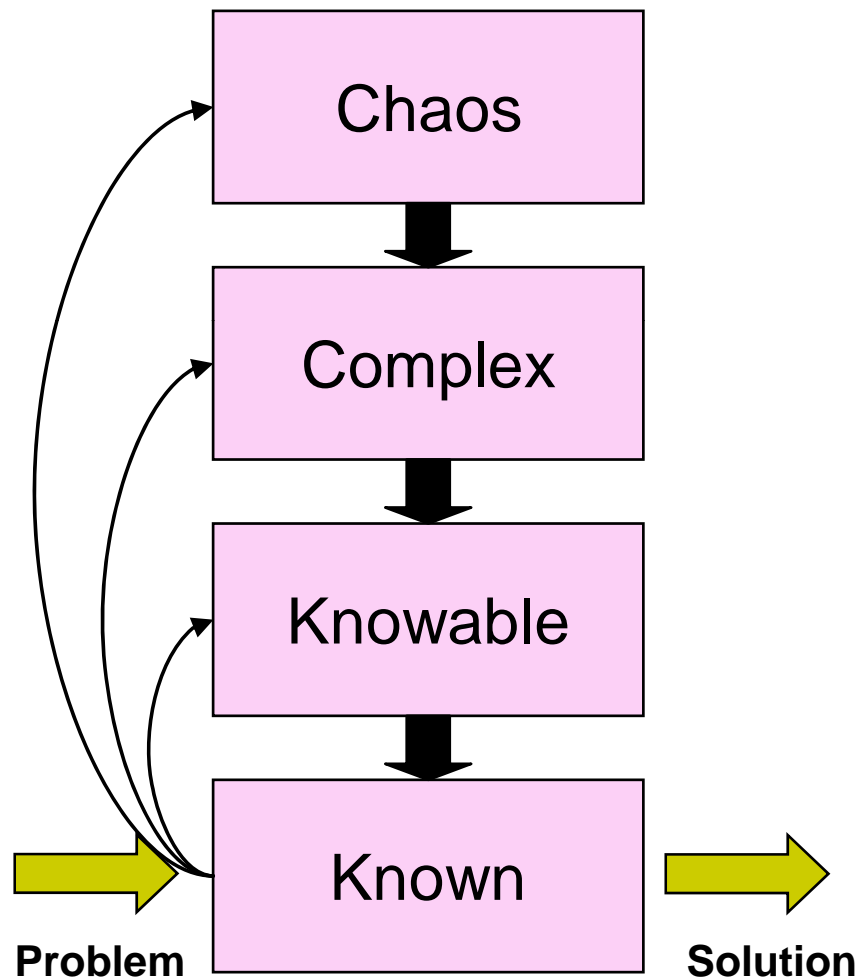


- **practical problems in the field.**
- Another source for research ideas is the **literature in your specific field.**
- good research ideas is the **Requests For Proposals (RFPs)** that are published by government agencies and some companies.
- And let's not forget the fact that many researchers simply **think up their research** topic on their own.



# Cynefin Domain

D. Snowden and F. Kurtz, "The new dynamics of strategy: Sense-making in a complex and complicated world", *IBM Systems Journal*, vol: 42, no: 3, 2003, pp. 462-483.



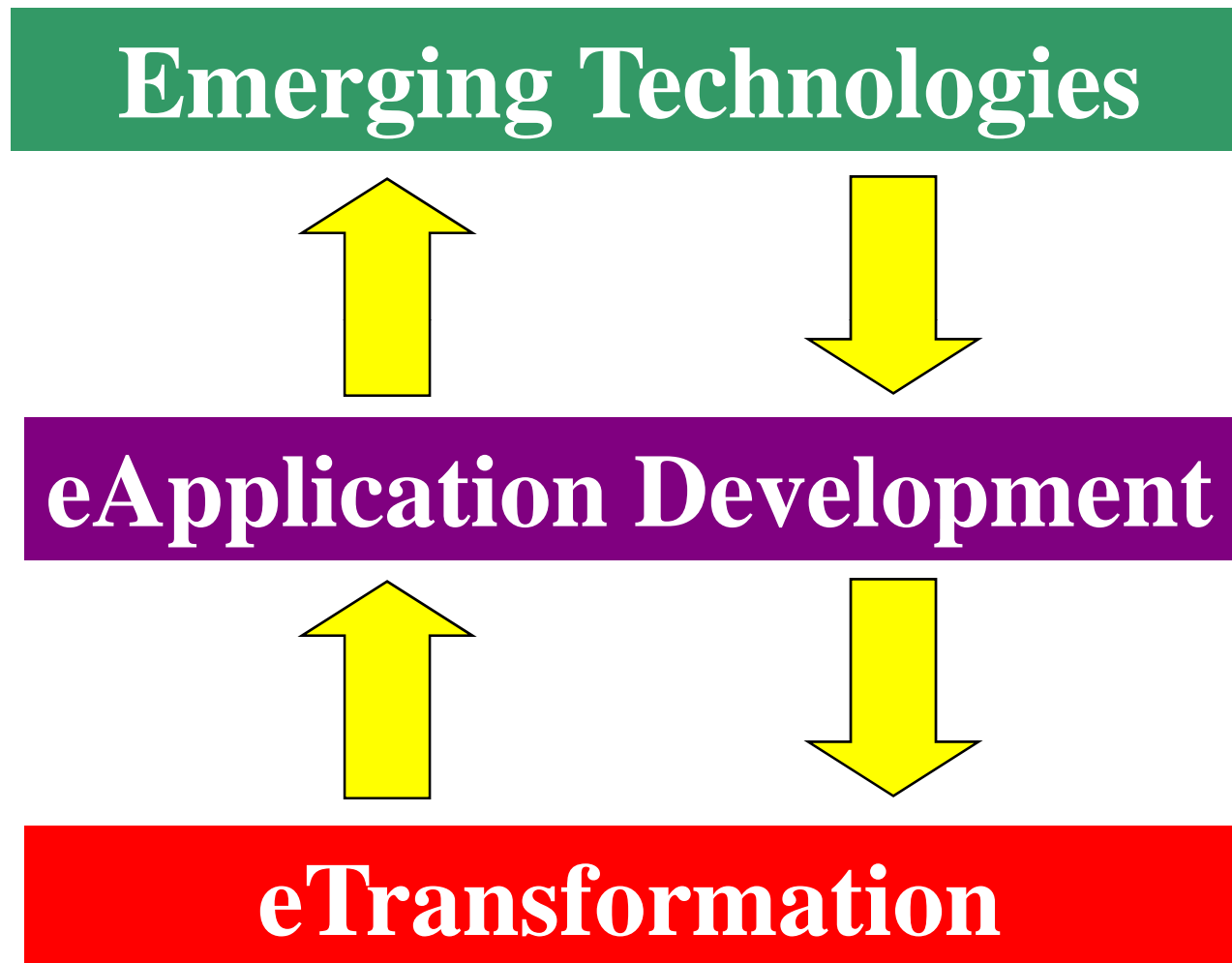
# Types of Research



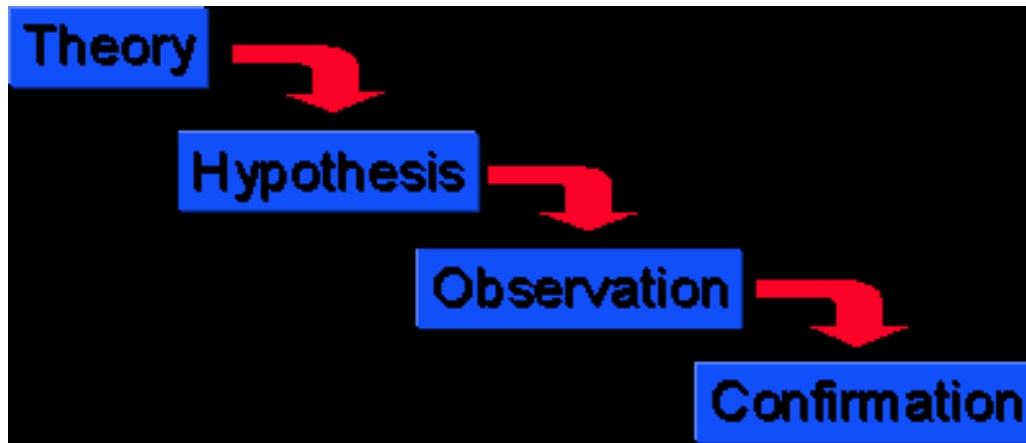
Research includes pure basic research, strategic basic research, applied research and experimental development [ABS 1998, *Australian Standard Research Classification*]

- **Pure basic research** is experimental and theoretical work undertaken to acquire new knowledge without looking for long-term benefits other than the advancement of knowledge.
- **Strategic basic research** is experimental and theoretical work undertaken to acquire new knowledge directed into specified broad areas in the expectation of useful discoveries. It provides the broad base of knowledge necessary for the solution of recognised practical problems.
- **Applied research** is original work undertaken primarily to acquire new knowledge with a specific application in view. It is undertaken either to determine possible uses for the findings of basic research or to determine new ways of achieving some specific and predetermined objectives.
- **Experimental development** is systematic work, using existing knowledge gained from research or practical experience, that is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed.

# Advance enterprise Information Management Systems Research Group

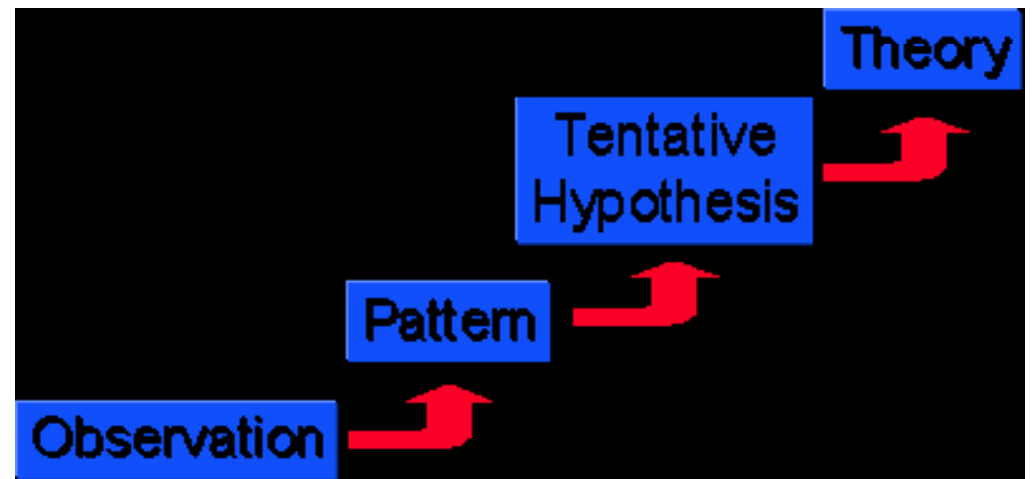


# Deduction & Induction [2]

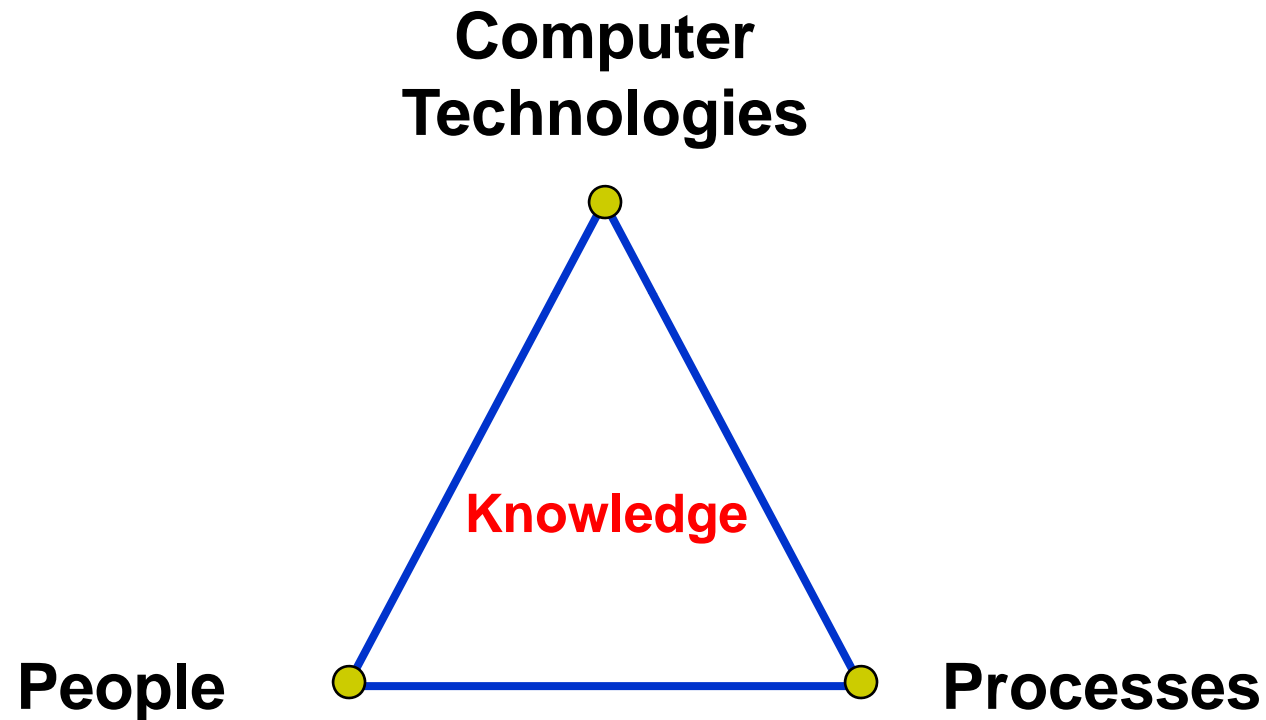


Deductive Thinking

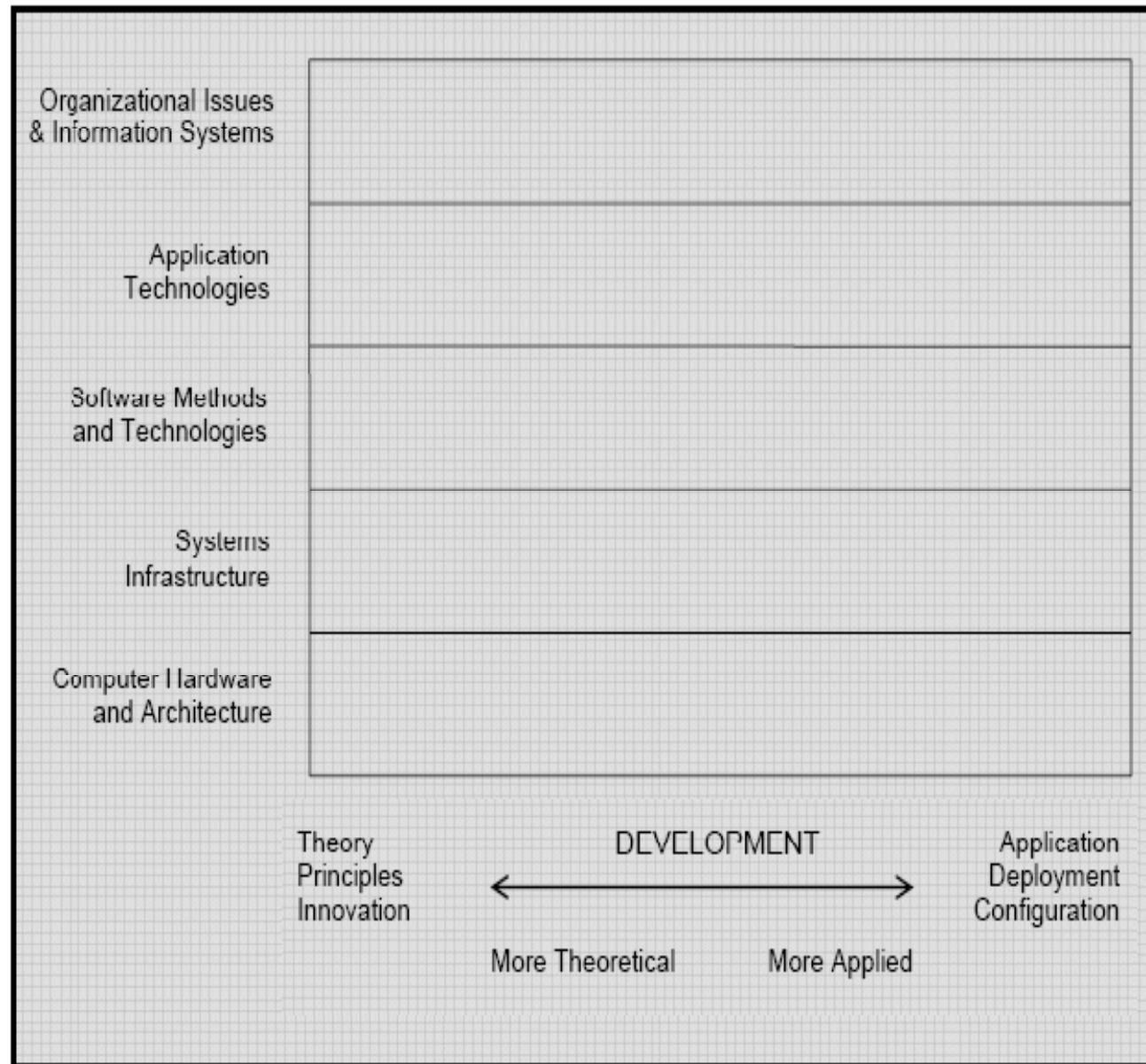
Inductive Thinking



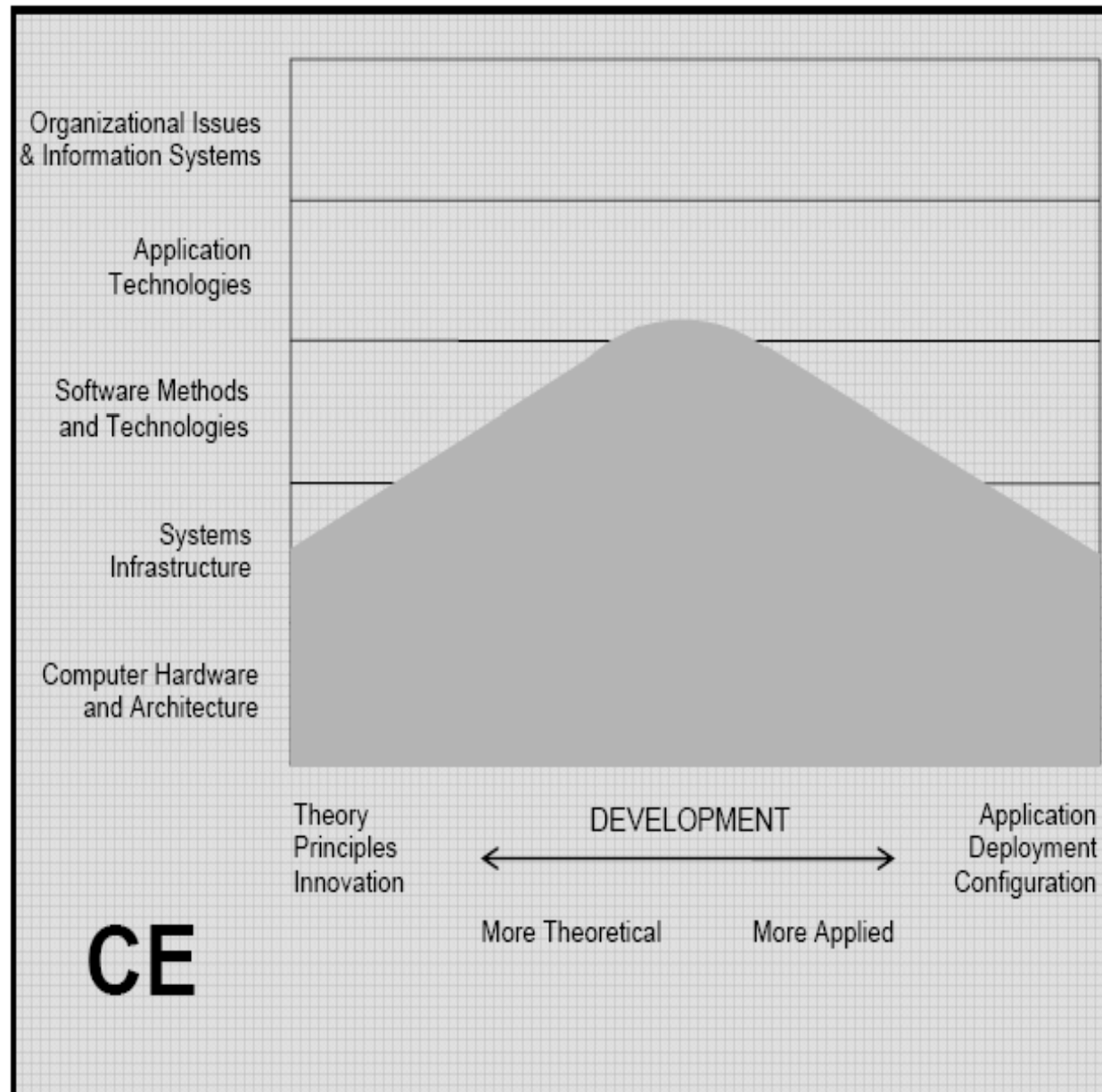
# Scope of Computing Research



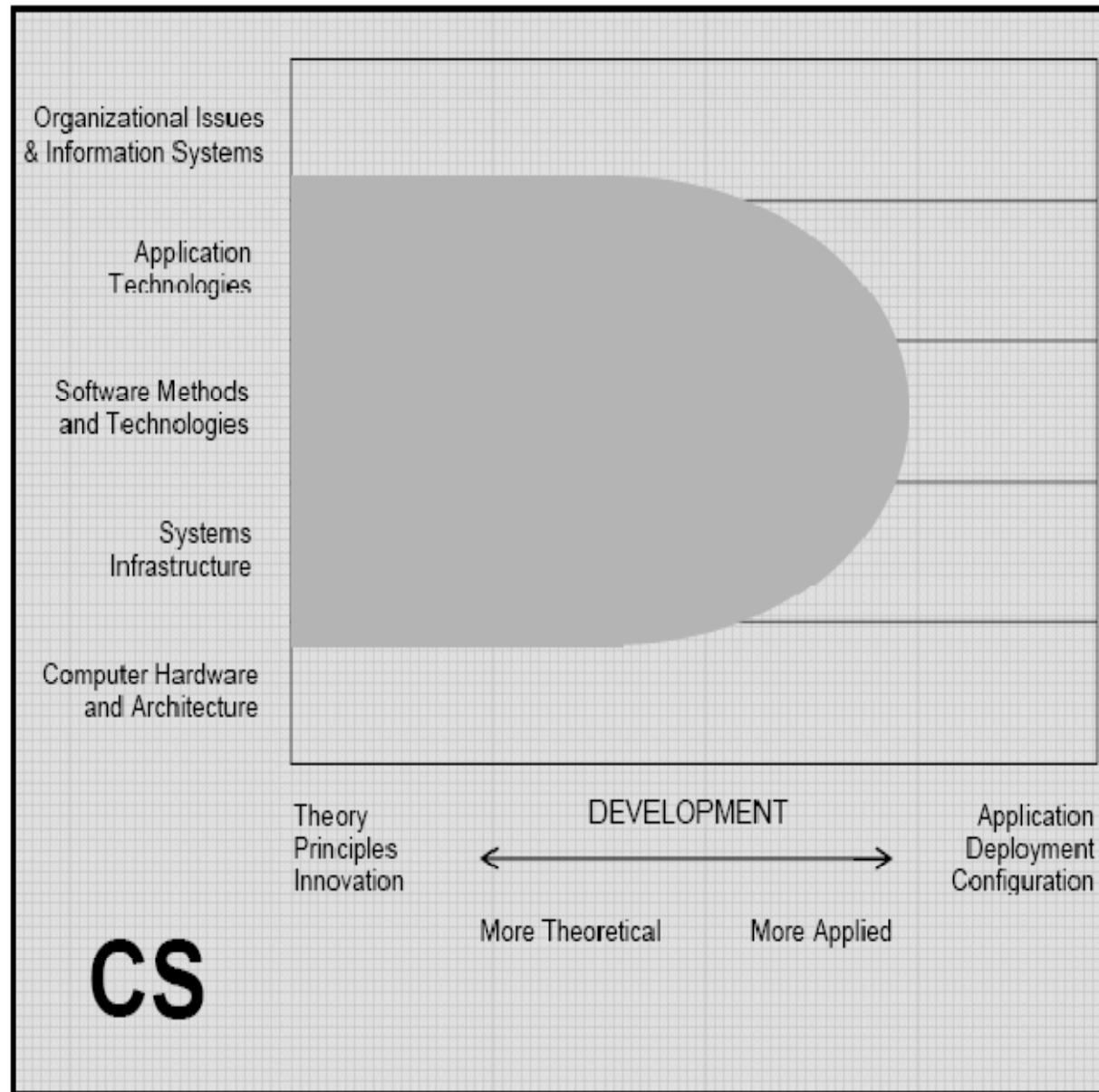
# Problem Space of Computing [5]



# Computer Engineering [5]

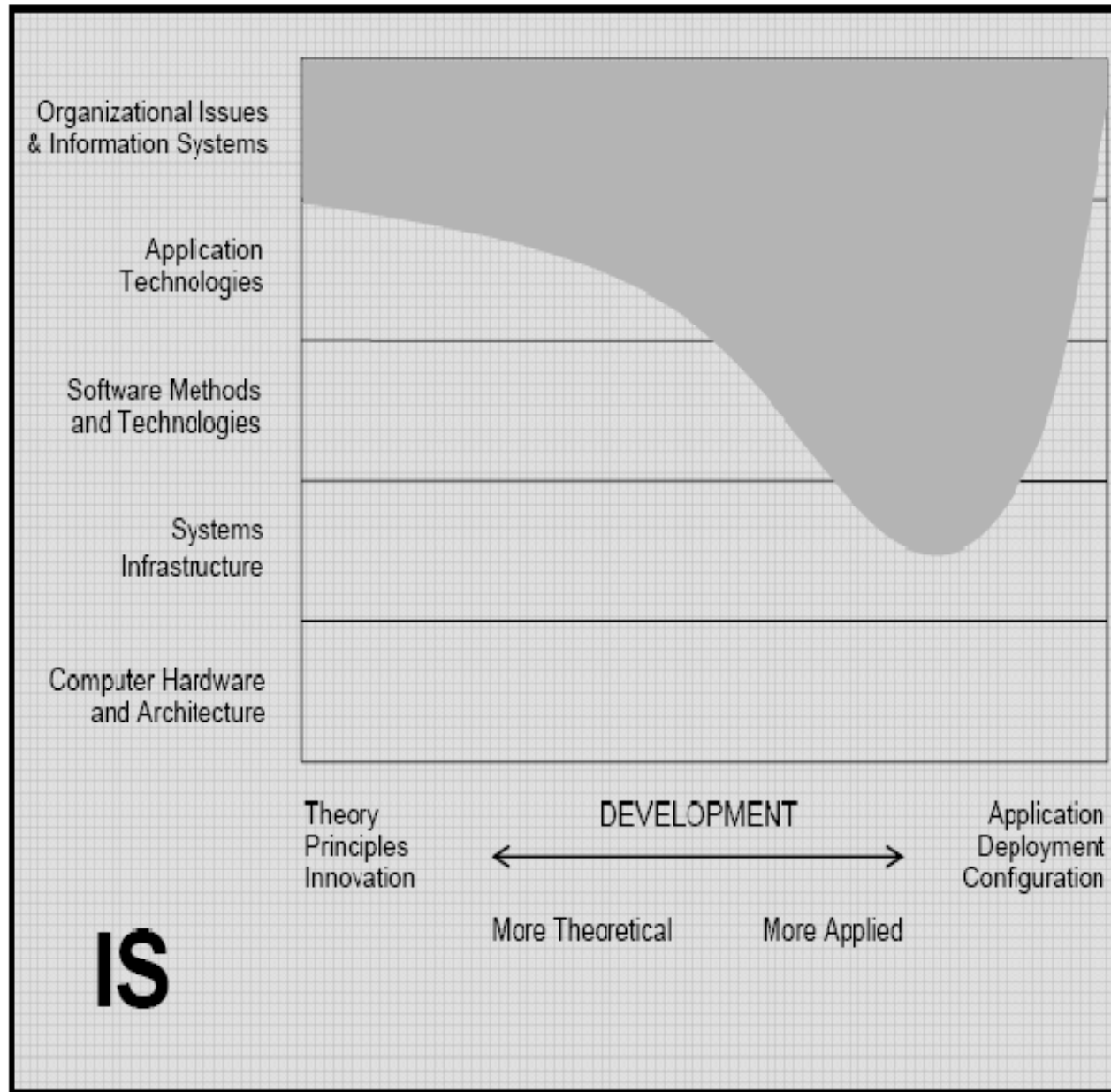


# Computer Science [5]

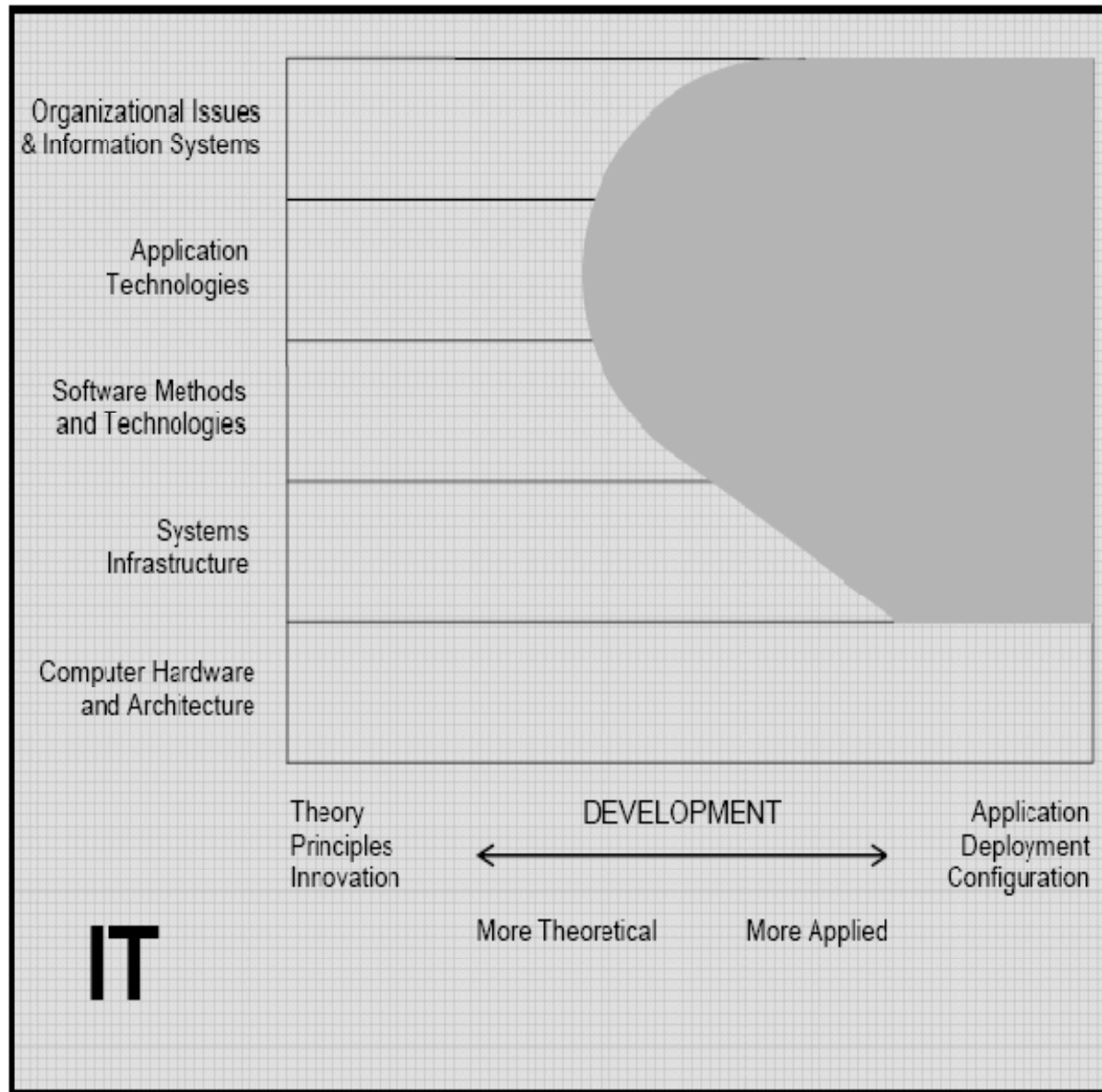




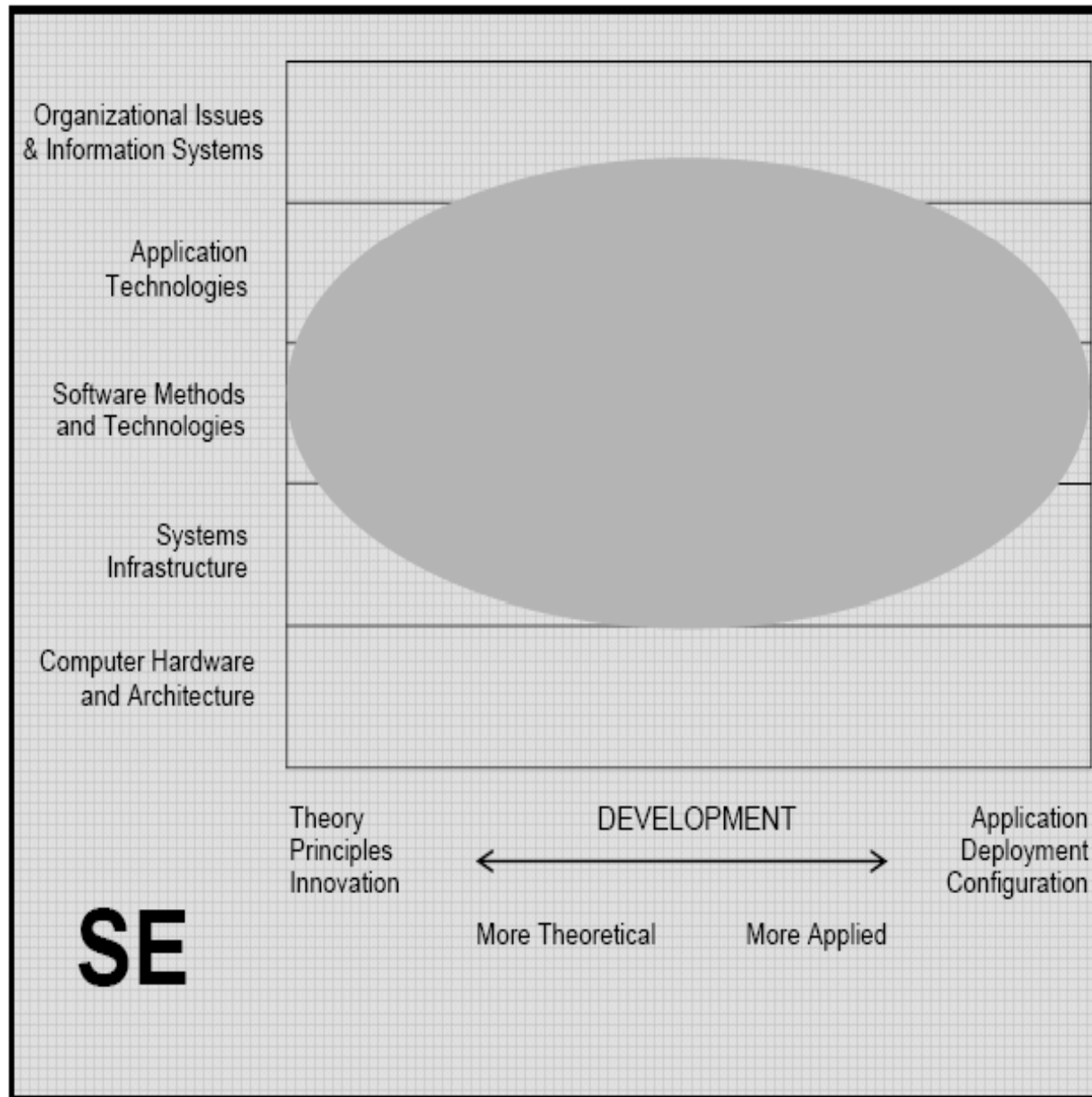
# Information Systems [5]



# Information Technology [5]



# Software Engineering



## Session 2: Some specific Research Methods



- A Taxonomy of relevant Research Methods
- Overall Process – Research Methodology

# Taxonomy of CRM [1]



- Glass, Ramesh and Vessey (GRV), a software engineer, a computer scientist, and an information scientist, respectively, recently developed a metadata set for research in the computing disciplines.
- GRV's metadata set consists of multiple taxonomies, one each for
  - topic,
  - research approach,
  - research method,
  - reference discipline,
  - level of analysis.

# GRV Taxonomies [6]



- **Topic** addresses the subject matter of the research. Topics covered are concepts associated with problem solving, computers, systems/software, data/information, problem domain-specific, systems/ software management, organizations, and society, as well as disciplinary issues. Each of these categories is further subdivided into a number of subcategories.
- **Research approach** addresses the general way the research is conducted. Approaches identified are descriptive, evaluative, and formulative, again with subcategories defined in each.
- **Research method** addresses the specific methods used. Research methods examined include conceptual analysis, case study, data analysis, field experiment, laboratory experiment, and simulation. Categories are not further subdivided.
- **Reference discipline** addresses the disciplines whose theories formed a basis for the research. Examples are cognitive psychology, social and behavioral science, economics, and management. We also included self-references, such as references to papers/theories in the discipline under examination.
- **Level of analysis** addresses the object on which the research study focused. Research can be conducted on both the technical level (such as computing element and abstract concept), and the behavioral level (such as society, profession, organizational, project, group/team, or individual).

# Topic



| Topic Categories |   | CS           | SE           | IS          | Topic Categories |   | CS          | SE           | IS           |
|------------------|---|--------------|--------------|-------------|------------------|---|-------------|--------------|--------------|
| <b>1.0</b>       | <b>Problem-Solving Concepts</b>   | <b>14.7%</b> | <b>5.9%</b>  | <b>5.9%</b> | <b>6.0</b>       | <b>Systems/software management concepts</b>                             |             | <b>11.5%</b> | <b>6.8%</b>  |
| 1.1              | Algorithms  | 5.8%         | 0.5%         | 0.2%        | 6.1              | Project/product management (incl. risk management)                      | 0.2%        | 3.3%         | 3.1%         |
| 1.2              | Mathematics/Computational Science   | 6.7%         | -            | -           | 6.2              | Process management  | -           | 2.2%         | 0.6%         |
| 1.3              | Methodologies (object, function/process, information/data, event, business rules, ...)          | -            | 4.9%         | 0.8%        | 6.3              | Measurement/metrics (development and use)                               | -           | 6.2%         | 0.8%         |
| 1.4              | Artificial Intelligence   | 2.4%         | 0.5%         | 4.9%        | 6.4              | Personnel issues  | -           | 0.3%         | -            |
|                  |   |              |              |             | 6.5              | Acquisition of (Packaged/Custom) Software                               | 0.2%        | 0.5%         | 2.3%         |
| <b>2.0</b>       | <b>Computer Concepts</b>  | <b>28.7%</b> | <b>10.9%</b> | <b>0.0%</b> | <b>7.0</b>       | <b>Organizational concepts</b>  | <b>0.3%</b> | <b>1.9%</b>  | <b>65.6%</b> |
| 2.1              | Computer/hardware principles/architecture   | 10.2%        | -            | -           | 7.1              | Organizational Structure  | -           | 0.5%         | 5.0%         |
| 2.2              | Intercomputer communication (networks, distributed systems)                                     | 17.7%        | 9.5%         | -           | 7.2              | Strategy  | -           | -            | 6.6%         |
| 2.3              | Operating systems (as an augmentation of hardware)  | 0.80%        | 1.4%         | -           | 7.3              | Alignment (incl. business process reengineering)                        | -           | 0.5%         | 6.9%         |
| 2.4              | Machine/assembler-level data/instructions   | -            | -            | -           | 7.4              | Organizational learning/knowledge management                            | -           | -            | 4.4%         |
|                  |   |              |              |             | 7.5              | Technology transfer (incl. innovation, acceptance, adoption, diffusion) | 0.1%        | 0.3%         | 19.4%        |
| <b>3.0</b>       | <b>Systems/software concepts</b>  | <b>19.1%</b> | <b>54.8%</b> | <b>6.4%</b> | 7.6              | Change management   | -           | -            | 1.6%         |
| 3.1              | System architecture/engineering   | 0.48%        | 1.9%         | 2.9%        | 7.7              | Information technology implementation                                   | -           | -            | 1.6%         |
| 3.2              | Software life cycle/engineering (incl. requirements, design, coding, testing, maintenance)      | -            | 8.7%         | 1.4%        | 7.8              | Information technology usage/operation                                  | -           | -            | 24.4%        |
| 3.3              | Programming languages   | 3.8%         | 3.8%         | 1.4%        | 7.9              | Management of "computing" function                                      | 0.2%        | -            | 11.6%        |
| 3.4              | Methods/techniques (incl. reuse, patterns, parallel processing, process models, data models...) | 3.8%         | 18.2%        | 0.2%        | 7.10             | IT Impact   | -           | 0.3%         | 15.3%        |
| 3.5              | Tools (incl. compilers, debuggers)  | 5.3%         | 12.2%        | 0.2%        | 7.11             | Computing/information as a business                                     | -           | -            | -            |
| 3.6              | Product quality (incl. performance, fault tolerance)  | 1.8%         | 8.4%         | 1.4%        | 7.12             | Legal/ethical/cultural/political (organizational) implications          | -           | 0.3%         | 3.4%         |
| 3.7              | Human-computer interaction  | 3.2%         | 1.1%         | 1.4%        |                  |   |             |              |              |
| 3.8              | System security   | 0.80%        | 0.5%         | 0.2%        |                  |   |             |              |              |
| <b>4.0</b>       | <b>Data/information concepts</b>  | <b>15.4%</b> | <b>7.6%</b>  | <b>3.0%</b> | <b>8.0</b>       | <b>Societal concepts</b>  | <b>-</b>    | <b>0.3%</b>  | <b>1.4%</b>  |
| 4.1              | Data/file structures  | 1.9%         | 0.8%         | -           | 8.1              | Cultural implications   | -           | -            | 0.2%         |
| 4.2              | Data base/warehouse/mart organization   | 8.4%         | 4.6%         | 1.6%        | 8.2              | Legal implications  | -           | -            | 0.2%         |
| 4.3              | Information retrieval   | 4.0%         | 1.4%         | 0.4%        | 8.3              | Ethical implications  | -           | -            | -            |
| 4.4              | Data analysis   | 0.64%        | 0.5%         | 0.6%        | 8.4              | Political implications  | -           | 0.3%         | 1.0%         |
| 4.5              | Data security   | 0.48%        | 0.3%         | 0.4%        |                  |   |             |              |              |
| <b>5.0</b>       | <b>Problem domain-specific concepts</b>   | <b>21.5%</b> | <b>2.7%</b>  | <b>6.4%</b> | <b>9.0</b>       | <b>Disciplinary issues</b>  | <b>-</b>    | <b>3.5%</b>  | <b>4.3%</b>  |
| 5.1              | Scientific/engineering (incl. bioinformatics)   | 0.48%        | 0.3%         | -           | 9.1              | "Computing" research  | -           | 1.1%         | 3.3%         |
| 5.2              | Information systems (incl. decision support, group support systems, expert systems)             | 0.64%        | 1.6%         | 6.4%        | 9.2              | "Computing" curriculum/teaching   | -           | 2.4%         | 1.0%         |
| 5.3              | Systems programming   | -            | -            | -           |                  |   |             |              |              |
| 5.4              | Real-time (incl. robotics)  | 0.16%        | 0.5%         | -           |                  |   |             |              |              |
| 5.5              | Edutainment (incl. graphics)  | 20.2%        | 0.3%         | -           |                  |   |             |              |              |



# Topic

| Topic Categories |   | CS           | SE           | IS          |
|------------------|---|--------------|--------------|-------------|
| <b>1.0</b>       | <b>Problem-Solving Concepts</b>   | <b>14.7%</b> | <b>5.9%</b>  | <b>5.9%</b> |
| 1.1              | Algorithms  | 5.8%         | 0.5%         | 0.2%        |
| 1.2              | Mathematics/Computational Science   | 6.7%         | -            | -           |
| 1.3              | Methodologies (object, function/process, information/data, event, business rules, ...)          | -            | 4.9%         | 0.8%        |
| 1.4              | Artificial Intelligence   | 2.4%         | 0.5%         | 4.9%        |
| <b>2.0</b>       | <b>Computer Concepts</b>  | <b>28.7%</b> | <b>10.9%</b> | <b>0.0%</b> |
| 2.1              | Computer/hardware principles/architecture   | 10.2%        | -            | -           |
| 2.2              | Intercomputer communication (networks, distributed systems)                                     | 17.7%        | 9.5%         | -           |
| 2.3              | Operating systems (as an augmentation of hardware)  | 0.80%        | 1.4%         | -           |
| 2.4              | Machine/assembler-level data/instructions   | -            | -            | -           |
| <b>3.0</b>       | <b>Systems/software concepts</b>  | <b>19.1%</b> | <b>54.8%</b> | <b>6.4%</b> |
| 3.1              | System architecture/engineering   | 0.48%        | 1.9%         | 2.9%        |
| 3.2              | Software life cycle/engineering (incl. requirements, design, coding, testing, maintenance)      | -            | 8.7%         | 1.4%        |
| 3.3              | Programming languages   | 3.8%         | 3.8%         | 1.4%        |
| 3.4              | Methods/techniques (incl. reuse, patterns, parallel processing, process models, data models...) | 3.8%         | 18.2%        | 0.2%        |
| 3.5              | Tools (incl. compilers, debuggers)  | 5.3%         | 12.2%        | 0.2%        |
| 3.6              | Product quality (incl. performance, fault tolerance)  | 1.8%         | 8.4%         | 1.4%        |
| 3.7              | Human-computer interaction  | 3.2%         | 1.1%         | 1.4%        |
| 3.8              | System security   | 0.80%        | 0.5%         | 0.2%        |



# Topic Cont.

| Topic Categories |   | CS           | SE           | IS          |
|------------------|---|--------------|--------------|-------------|
| <b>4.0</b>       | <b>Data/information concepts</b>  | <b>15.4%</b> | <b>7.6%</b>  | <b>3.0%</b> |
| 4.1              | Data/file structures  | 1.9%         | 0.8%         | -           |
| 4.2              | Data base/warehouse/mart organization   | 8.4%         | 4.6%         | 1.6%        |
| 4.3              | Information retrieval   | 4.0%         | 1.4%         | 0.4%        |
| 4.4              | Data analysis   | 0.64%        | 0.5%         | 0.6%        |
| 4.5              | Data security   | 0.48%        | 0.3%         | 0.4%        |
| <b>5.0</b>       | <b>Problem domain-specific concepts</b>   | <b>21.5%</b> | <b>2.7%</b>  | <b>6.4%</b> |
| 5.1              | Scientific/engineering (incl. bioinformatics)                                       | 0.48%        | 0.3%         | -           |
| 5.2              | Information systems (incl. decision support, group support systems, expert systems) | 0.64%        | 1.6%         | 6.4%        |
| 5.3              | Systems programming   | -            | -            | -           |
| 5.4              | Real-time (incl. robotics)  | 0.16%        | 0.5%         | -           |
| 5.5              | Edutainment (incl. graphics)  | 20.2%        | 0.3%         | -           |
| <b>6.0</b>       | <b>Systems/software management concepts</b>   |              | <b>11.5%</b> | <b>6.8%</b> |
| 6.1              | Project/product management (incl. risk management)                                  | 0.2%         | 3.3%         | 3.1%        |
| 6.2              | Process management  | -            | 2.2%         | 0.6%        |
| 6.3              | Measurement/metrics (development and use)   | -            | 6.2%         | 0.8%        |
| 6.4              | Personnel issues  | -            | 0.3%         | -           |
| 6.5              | Acquisition of (Packaged/Custom) Software   | 0.2%         | 0.5%         | 2.3%        |

# Topic Cont.

| Topic Categories |   | CS          | SE          | IS           |
|------------------|---|-------------|-------------|--------------|
| <b>7.0</b>       | <b>Organizational concepts</b>  | <b>0.3%</b> | <b>1.9%</b> | <b>65.6%</b> |
| 7.1              | Organizational Structure  | -           | 0.5%        | 5.0%         |
| 7.2              | Strategy  | -           | -           | 6.6%         |
| 7.3              | Alignment (incl. business process reengineering)                        | -           | 0.5%        | 6.9%         |
| 7.4              | Organizational learning/knowledge management                            | -           | -           | 4.4%         |
| 7.5              | Technology transfer (incl. innovation, acceptance, adoption, diffusion) | 0.1%        | 0.3%        | 19.4%        |
| 7.6              | Change management   | -           | -           | 1.6%         |
| 7.7              | Information technology implementation                                   | -           | -           | 1.6%         |
| 7.8              | Information technology usage/operation                                  | -           | -           | 24.4%        |
| 7.9              | Management of "computing" function                                      | 0.2%        | -           | 11.6%        |
| 7.10             | IT Impact   | -           | 0.3%        | 15.3%        |
| 7.11             | Computing/information as a business                                     | -           | -           | -            |
| 7.12             | Legal/ethical/cultural/political (organizational) implications          | -           | 0.3%        | 3.4%         |
| <b>8.0</b>       | <b>Societal concepts</b>  | <b>-</b>    | <b>0.3%</b> | <b>1.4%</b>  |
| 8.1              | Cultural implications   | -           | -           | 0.2%         |
| 8.2              | Legal implications  | -           | -           | 0.2%         |
| 8.3              | Ethical implications  | -           | -           | -            |
| 8.4              | Political implications  | -           | 0.3%        | 1.0%         |
| <b>9.0</b>       | <b>Disciplinary issues</b>  | <b>-</b>    | <b>3.5%</b> | <b>4.3%</b>  |
| 9.1              | "Computing" research  | -           | 1.1%        | 3.3%         |
| 9.2              | "Computing" curriculum/teaching   | -           | 2.4%        | 1.0%         |

# Research Approach

| Research Approach   |  | CS           | SE           | IS           |
|---------------------|--|--------------|--------------|--------------|
| <b>Descriptive:</b> |  | <b>9.9%</b>  | <b>27.9%</b> | <b>9.0%</b>  |
| DS                  | Descriptive System                     | 4.1%         | 8.1%         | 2.7%         |
| DR                  | Review of Literature                   | 0.6%         | 1.6%         | -            |
| DO                  | Descriptive Other                      | 5.1%         | 18.2 %       | 6.3%         |
| <b>Evaluative:</b>  |  | <b>11.0%</b> | <b>13.8%</b> | <b>66.8%</b> |
| ED                  | Evaluative-deductive                   | 1.1%         | 4.3%         | 46.7%        |
| EI                  | Evaluative-interpretive                | -            | <1%          | 4.7%         |
| EC                  | Evaluative-critical                    | -            | 1.4%         | -            |
| EO                  | Evaluative-other                       | 9.9%         | 7.3%         | 15.4%        |
| <b>Formulative:</b> |  | <b>79.1%</b> | <b>55.3%</b> | <b>24.2%</b> |
| FC                  | Formulative-concept                    | 17.0%        | 3.0%         | 1.0%         |
| FF                  | Formulative-framework                  | 2.4%         | 4.1%         | 2.5%         |
| FG                  | Formulative-guidelines/standards       | 0.6%         | 4.3%         | 0.8%         |
| FM                  | Formulative-model                      | 5.7%         | 9.8%         | 12.5%        |
| FP                  | Formulative-process, method, algorithm | 52.6%        | 36.0%        | 4.7%         |
| FT                  | Formulative-classification/taxonomy    | 0.8%         | 1.1%         | 2.7%         |

# Research Methods

| Research Method |   | CS    | SE    | IS    |
|-----------------|---|-------|-------|-------|
| AR              | Action Research                           | -     | 0%    | 0.8%  |
| CA              | Conceptual Analysis                       | 15.1% | 43.5% | 14.7% |
| CAM             | Conceptual Analysis/Mathematical          | 73.4% | 10.6% | 12.1% |
| CI              | Concept Implementation (Proof of Concept) | 2.9%  | 17.1% | 1.6%  |
| CS              | Case Study                                | 0.2%  | 2.2%  | 12.5% |
| DA              | Data Analysis                             | 0.2%  | 2.2%  | 5.3%  |
| ET              | Ethnography                               | -     | -     | 0.2%  |
| FE              | Field Experiment                          | -     | <1%   | 1.6%  |
| FS              | Field Study                               | 0.2%  | <1%   | 24.5% |
| GT              | Grounded Theory                           | -     | <1%   | 0.2%  |
| HE              | Hermeneutics                              | -     | <1%   | -     |
| ID              | Instrument Development                    | -     | -     | 3.5%  |
| LH              | Laboratory Experiment - Human Subjects    | 1.8%  | 3.0%  | 16.2% |
| LR              | Literature Review/analysis                | .3%   | 1.1%  | 0.8%  |
| LS              | Laboratory Experiment - Software          | 1.9%  | <1%   | 0.6%  |
| MP              | Mathematical Proof                        | 2.4%  | <1%   | 0.2%  |
| PA              | Protocol Analysis                         | -     | -     | 1.2%  |
| SI              | Simulation                                | 1.8%  | 1.1%  | 1.4%  |
| ES              | Descriptive/Exploratory Survey            | -     | 1.6%  | 2.7%  |

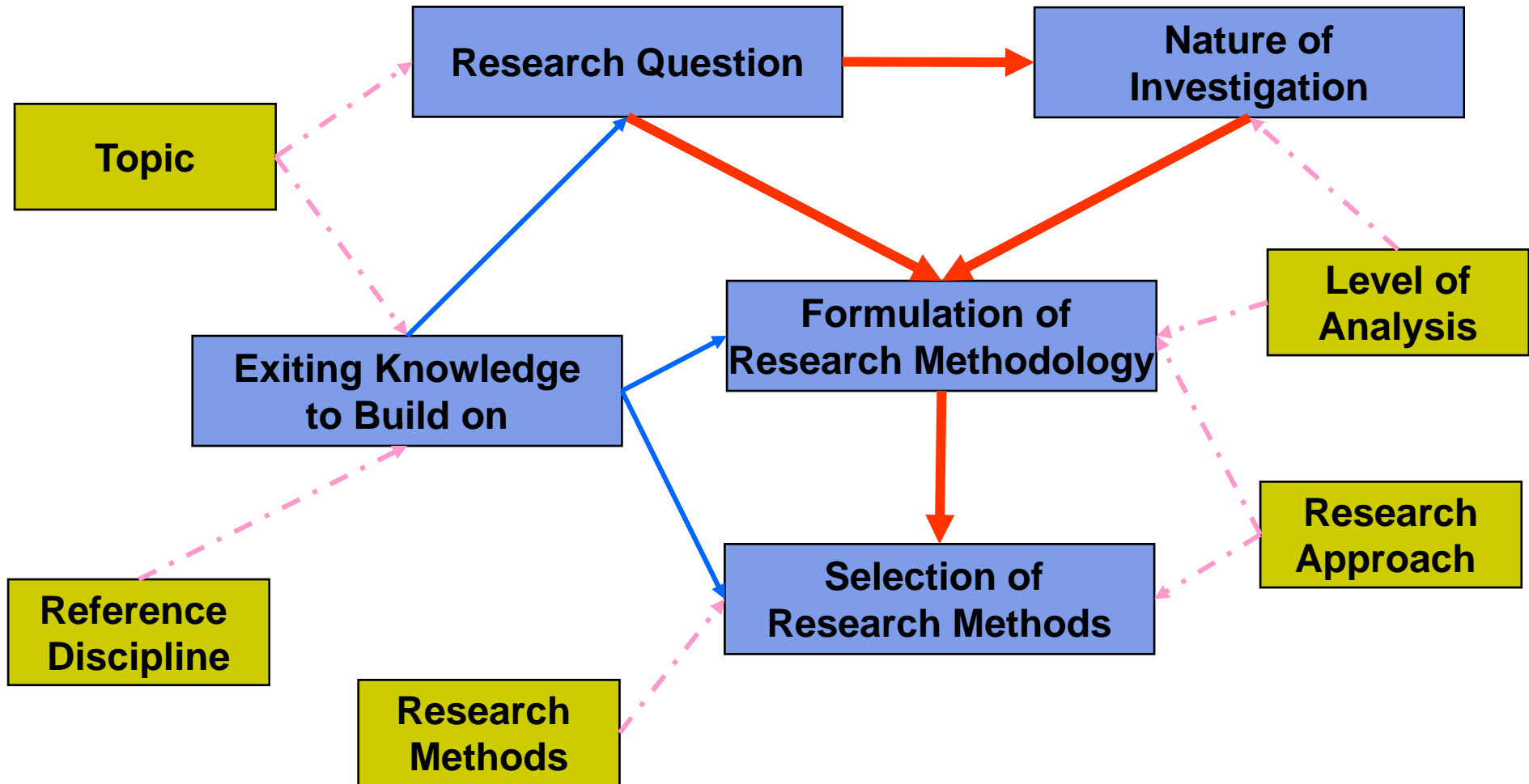
# Reference Discipline

| Reference Discipline |                               | CS     | SE    | IS    |
|----------------------|-------------------------------|--------|-------|-------|
| CP                   | Cognitive Psychology          | 0.80%  | 0.54% | 10.7% |
| SB                   | Social and Behavioral Science | -      | 0.27% | 9.0%  |
| SC                   | Science                       | 0.96%  | 0.27% | -     |
| EC                   | Economics                     | -      | -     | 11.1% |
| MG                   | Management                    | -      | 0.27% | 18.0% |
| MS                   | Management Science            | -      | 0.27% | 6.6%  |
| MA                   | Mathematics                   | 8.60%  | -     | -     |
| OT                   | Other                         | 0.32%  | 0.27% | 12.5% |
| NA                   | Not applicable                | -      | -     | 4.9%  |
| SR                   | Self-Reference                | 89.33% | 98.1% | 27.2% |

# Level of Analysis

|     | Level of Analysis                                 | CS     | SE    | IS    |
|-----|---|--------|-------|-------|
| SOC | Society   | -      | 0.27% | 3.1%  |
| PRO | Profession  | .32%   | 2.4%  | 1.8%  |
| EXT | External Business Context                         | -      | -     | 5.1%  |
| OC  | Organizational Context                            | -      | 2.2%  | 25.6% |
| PR  | Project   | -      | 4.1%  | 8.8%  |
| GP  | Group/Team  | -      | 1.4%  | 10.9% |
| IN  | Individual  | 1.91%  | 1.4%  | 23.8% |
| AC  | Abstract Concept                                  | 38.85% | 49.9% | 8.8%  |
| CS  | System  | 5.57%  | 10.6% | 7.2%  |
| CE  | Computing Element - Program, component, algorithm | 53.34% | 27.9% | 4.9%  |

# Use of GRV Taxonomy



# Research Methods

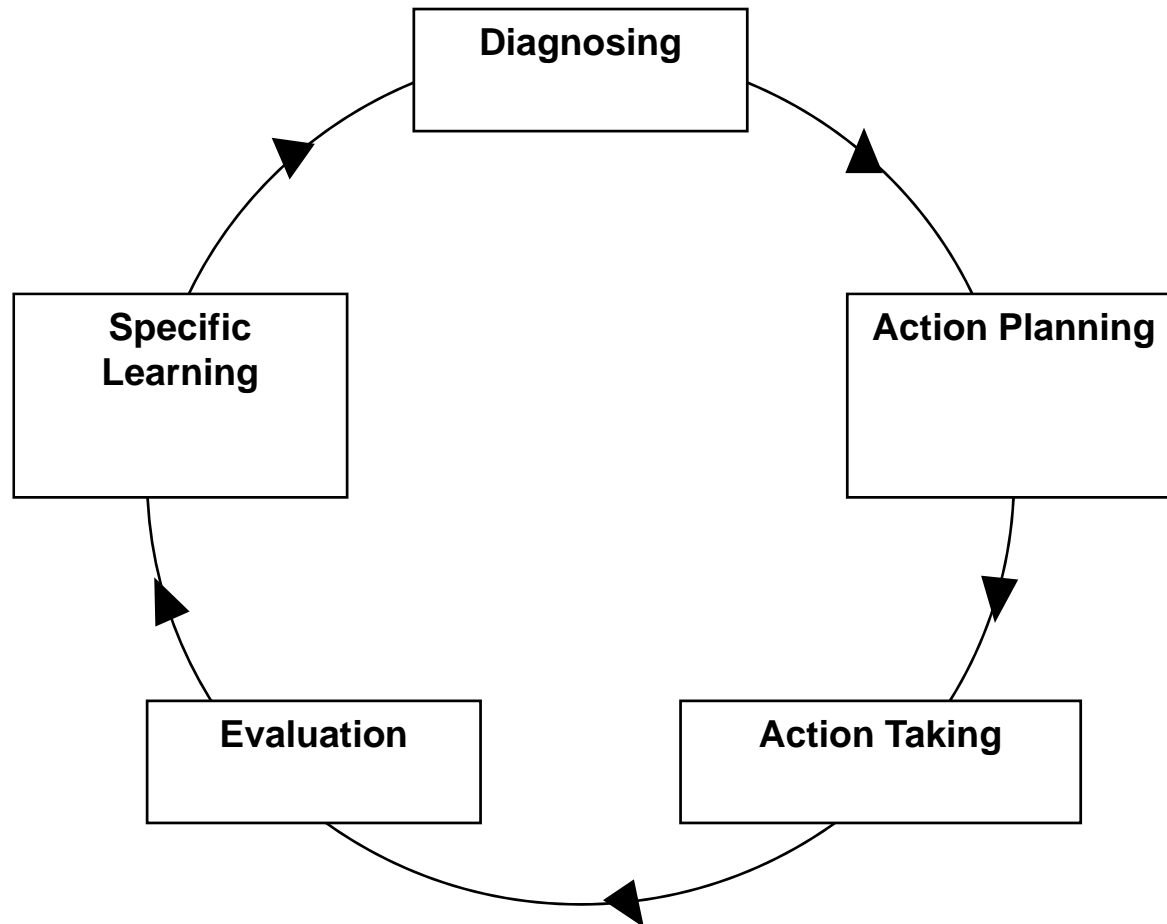


1. Action research;
2. Conceptual analysis;
3. conceptual analysis/mathematical;
4. Concept implementation (proof of concept);
5. case study;
6. data analysis;
7. descriptive/exploratory survey;
8. ethnography;
9. field experiment;
10. field study;
11. grounded theory;
12. hermeneutics;
13. Instrument development;
14. laboratory experiment – human subjects;
15. Laboratory experiment – software;
16. literature review/analysis;
17. Mathematical proof;
18. protocol analysis;
19. simulation.

- R.L. Glass, V. Ramesh, and I. Vessey. An analysis of research in computing disciplines. *Commun. ACM*, 47(6):89–94, June 2004.



# Action Research



# Conceptual Analysis [3]



- Conceptual analysis consists primarily in breaking down or analyzing concepts into their constituent parts in order to gain knowledge or a better understanding of a particular philosophical issue in which the concept is involved (Beaney 2003).
- For example, the [problem of free will](#) in philosophy involves various key concepts, including the concepts of freedom, moral responsibility, determinism, ability, and so on. The method of conceptual analysis tends to approach such a problem by breaking down the key concepts pertaining to the problem and seeing how they interact. Thus, in the long-standing debate on whether [free will](#) is compatible with the doctrine of [determinism](#), several philosophers have proposed analyses of the relevant concepts to argue for either [compatibilism](#) or [incompatibilism](#).

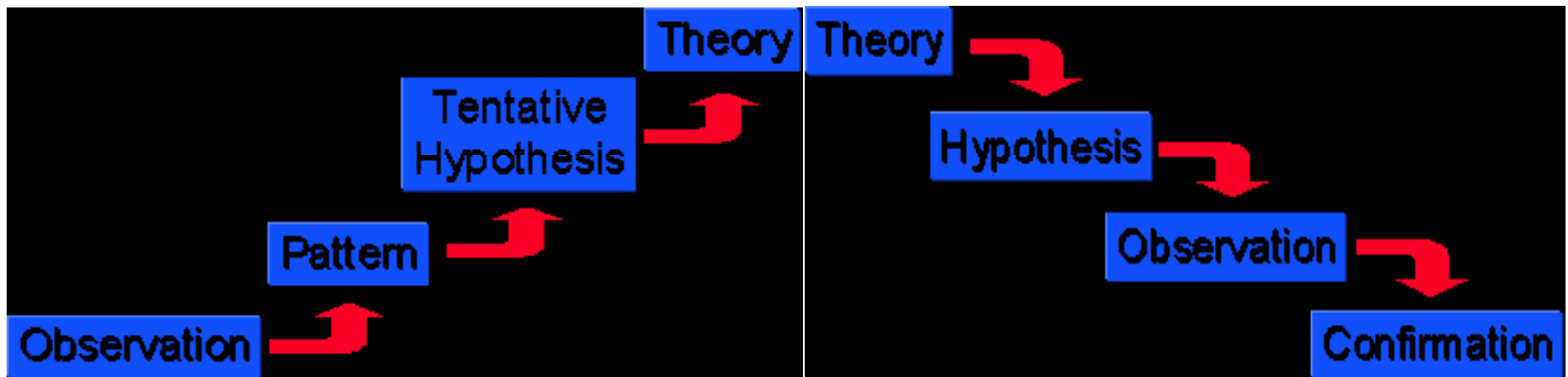
# Ethnography [3]



- **Ethnography** (ἔθνος *ethnos* = people and γράφειν *graphein* = writing) is the genre of writing that presents varying degrees of [qualitative](#) and [quantitative](#) descriptions of human social phenomena, based on [fieldwork](#).
- Ethnography presents the results of a [holistic](#) research method founded on the idea that a system's properties cannot necessarily be accurately understood independently of each other. The genre has both formal and historical connections to [travel writing](#) and colonial office reports. Several academic traditions, in particular the [constructivist](#) and [relativist](#) paradigms, employ ethnographic research as a crucial research method. Many [cultural anthropologists](#) consider ethnography the essence of the discipline.

# Grounded Theory [3]

- GT is a systematic generation of theory from data that contains both inductive and deductive thinking.
- One goal of a GT is to formulate hypotheses based on conceptual ideas. Others may try to verify the hypotheses that are generated by constantly comparing conceptualized data on different levels of abstraction, and these comparisons contain deductive steps. (Glaser & Strauss 1967).



# Hermeneutics [3]



- **Hermeneutics** may be described as the development and study of [theories](#) of the [interpretation](#) and understanding of texts. In contemporary usage in religious studies, hermeneutics refers to the study of the interpretation of religious texts. It is more broadly used in contemporary philosophy to denote the study of theories and methods of the interpretation of all texts and systems of meaning. The concept of "text" is here extended beyond [written documents](#) to any number of objects subject to interpretation, such as experiences. A hermeneutic is defined as a specific system or method for interpretation, or a specific theory of interpretation. However, the contemporary philosopher [Hans-Georg Gadamer](#) has said that hermeneutics is an approach rather than a method and, further, that the [Hermeneutic circle](#) is the central problem of interpretation.
- Essentially, hermeneutics involves cultivating the ability to understand things from somebody else's point of view, and to appreciate the cultural and social forces that may have influenced their outlook. Hermeneutics is the process of applying this understanding to interpreting the meaning of written texts and symbolic artifacts (such as art or sculpture or architecture), which may be either historic or contemporary.

# Research Methods



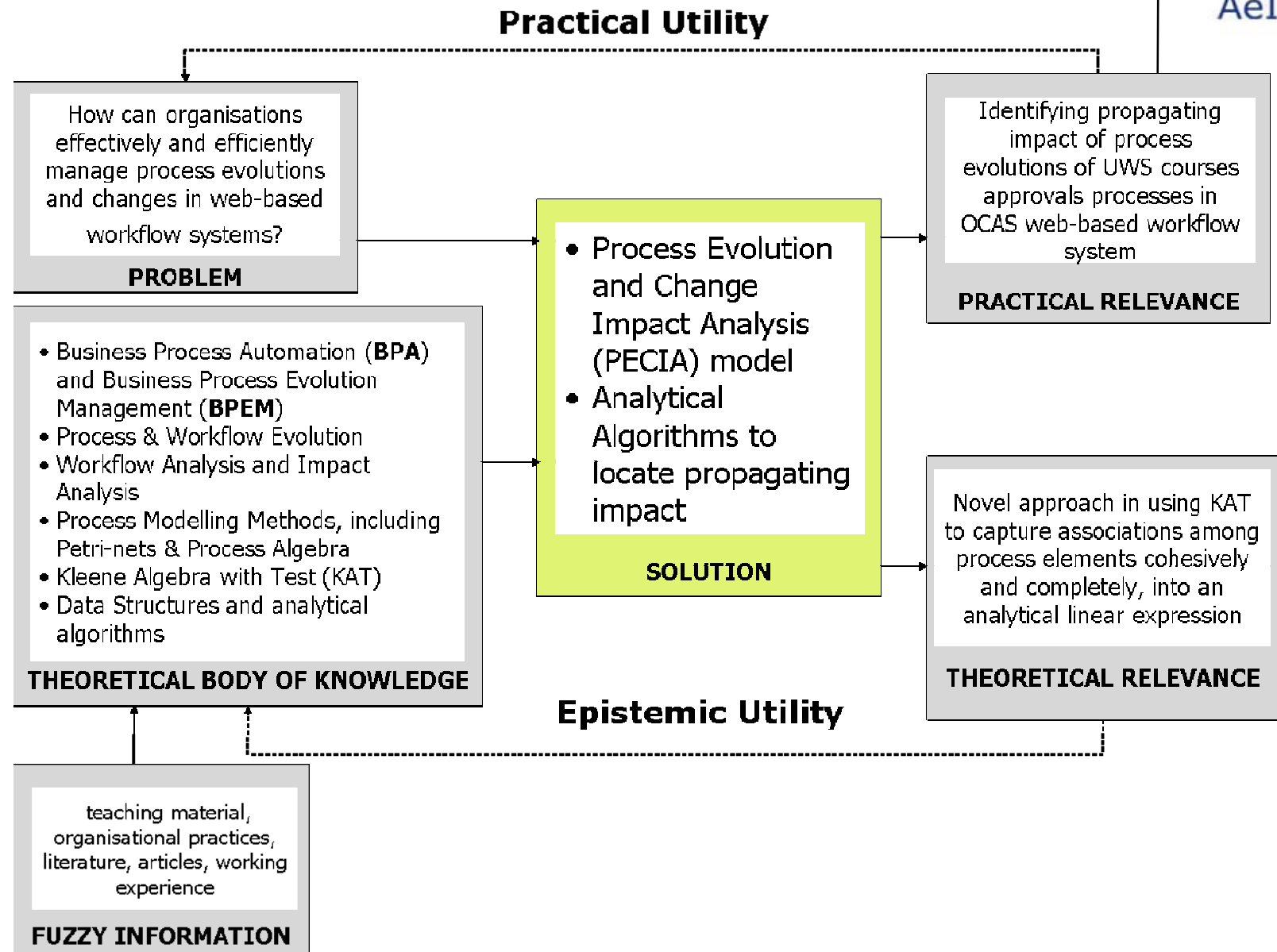
1. action research;
2. Conceptual analysis;
3. conceptual analysis/mathematical;
4. Concept implementation (proof of concept);
5. case study;
6. data analysis;
7. descriptive/exploratory survey;
8. ethnography;
9. field experiment;
10. field study;
11. grounded theory;
12. hermeneutics;
13. Instrument development;
14. laboratory experiment – human subjects;
15. Laboratory experiment – software;
16. literature review/analysis;
17. Mathematical proof;
18. protocol analysis;
19. simulation.

# Overall Process



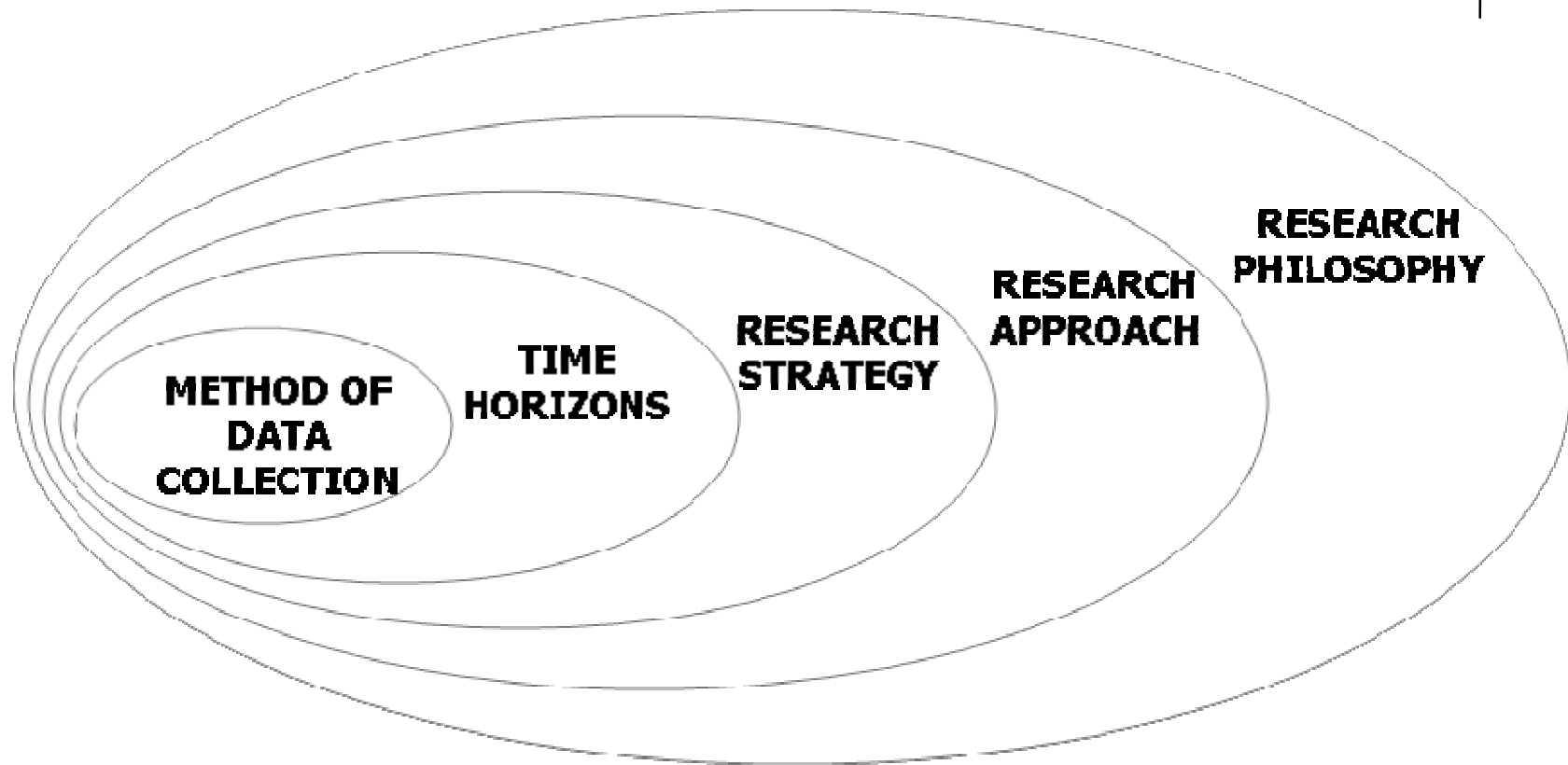
- Research Approach
  - Descriptive
  - Evaluative
  - Formulative

# Example: Formulative Approach

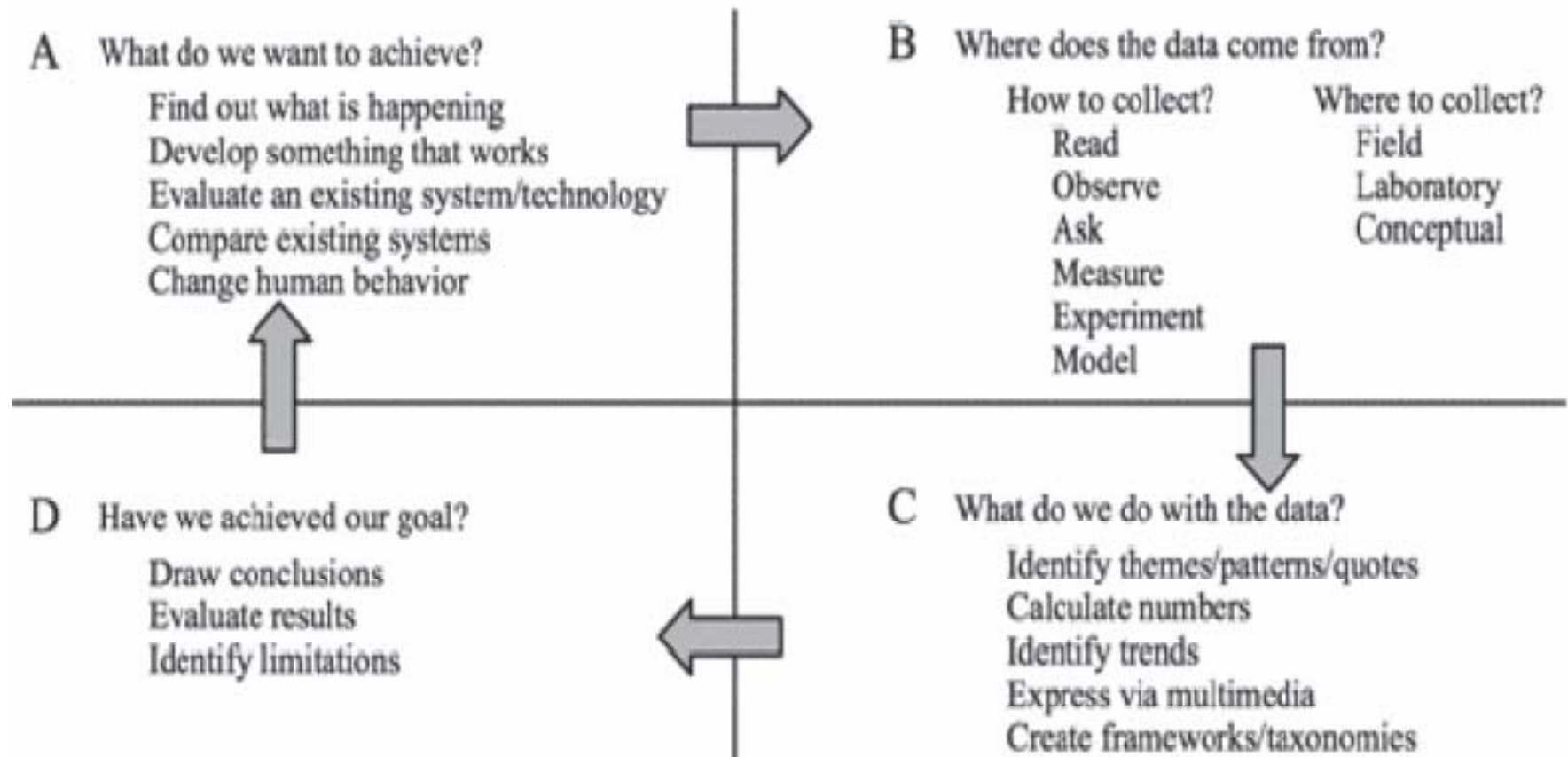




# Research Process Onion [7]



# Formulating Overall Process [1]



# An Example [1]



- Here we apply our framework in analyzing an example of typical research in the area of Human Computer Interaction. The paper by Beymer, et al, “Wide vs. Narrow Paragraphs: An Eye Tracking Analysis” [8] demonstrates human factors research and how such research depends on more fundamental investigations in perceptual and cognitive psychology. The paper follows two iterations of our framework.
  - **A.** What did they want to achieve? (Find out what is happening) The authors wished to achieve a better understanding of human behavior when reading columns of text on a computer screen.
  - **B.** Where did the data come from? (Read) The authors surveyed the early literature by typographers, psychologists, designers, and ergonomists.
  - **C.** What did they do with the data? (Identify themes) The authors collated the information from the literature, so as to better understand its conclusions. Thus, the first iteration used the specific CRM critical analysis of the literature.
  - **D.** Had they achieved their goal? (Draw conclusions, identify limitations) The authors now knew a great deal more about human reading of printed material, and online reading, but noted that these prior studies produced contradictory results and used dated technology.

# Session 3: Research Methods for Participants' Research questions



## Session 4: Case Studies



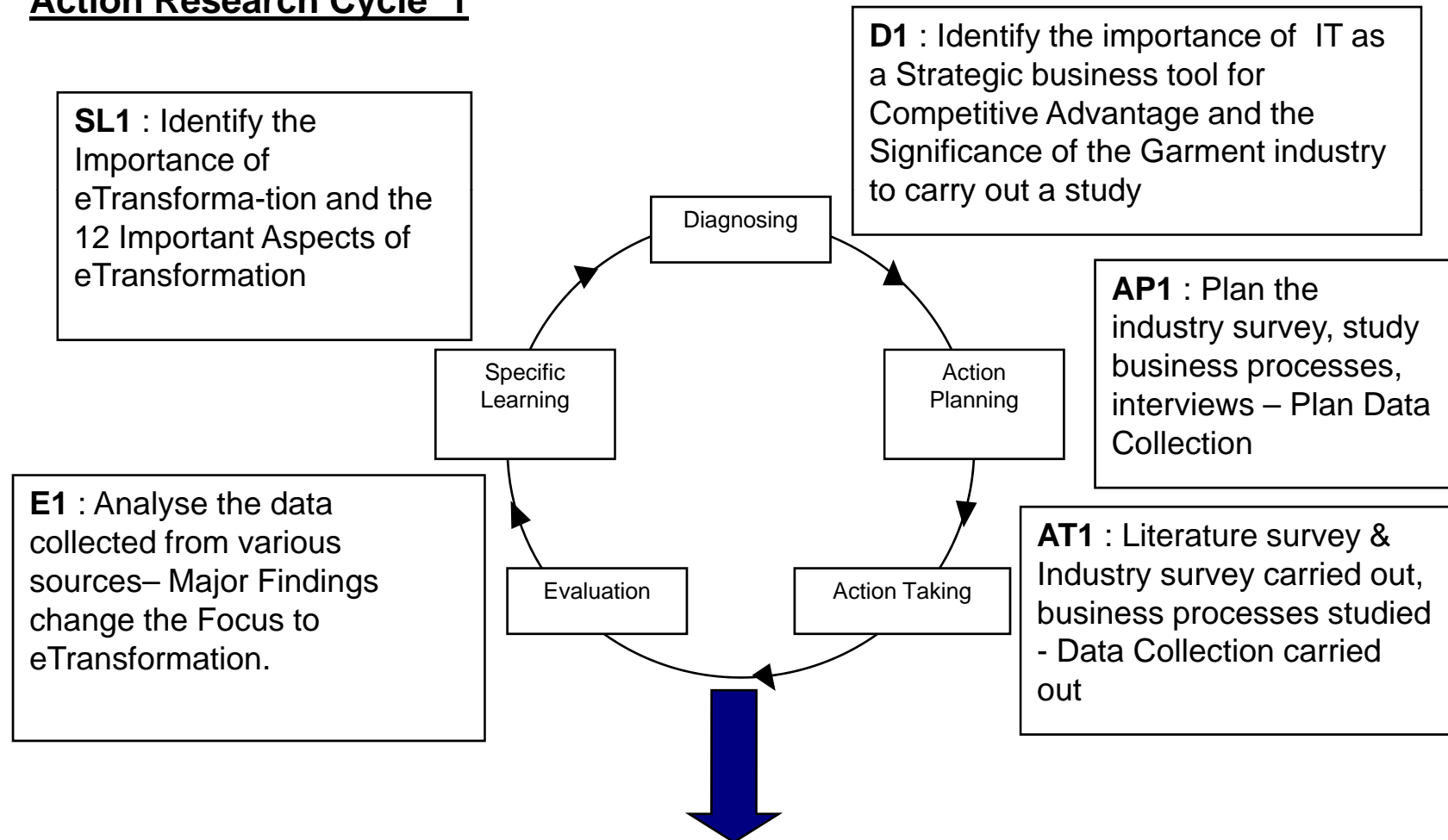
- *How can SMEs in the Manufacturing Sector Strategically eTransform to gain the Competitive Advantage in the Global Market? (Shiromi – Explicit RQ)*
- Enhancing Retrieval of Images on the Web Through Effective Use of Associated Text and Semantics from Low-Level Image Features (Lakshman – Implicit RQ)
- “How can organisations, accurately and effectively manage business process evolutions and changes in web-based workflows? (Anupama – Explicit RQ)

- *How can SMEs in the Manufacturing Sector Strategically eTransform to gain the Competitive Advantage in the Global Market? (Shiromi – Explicit RQ)*
- Stared with a survey and literature review to find the answer. Evolved into 3 action research cycles.

# Action Research Cycle 1

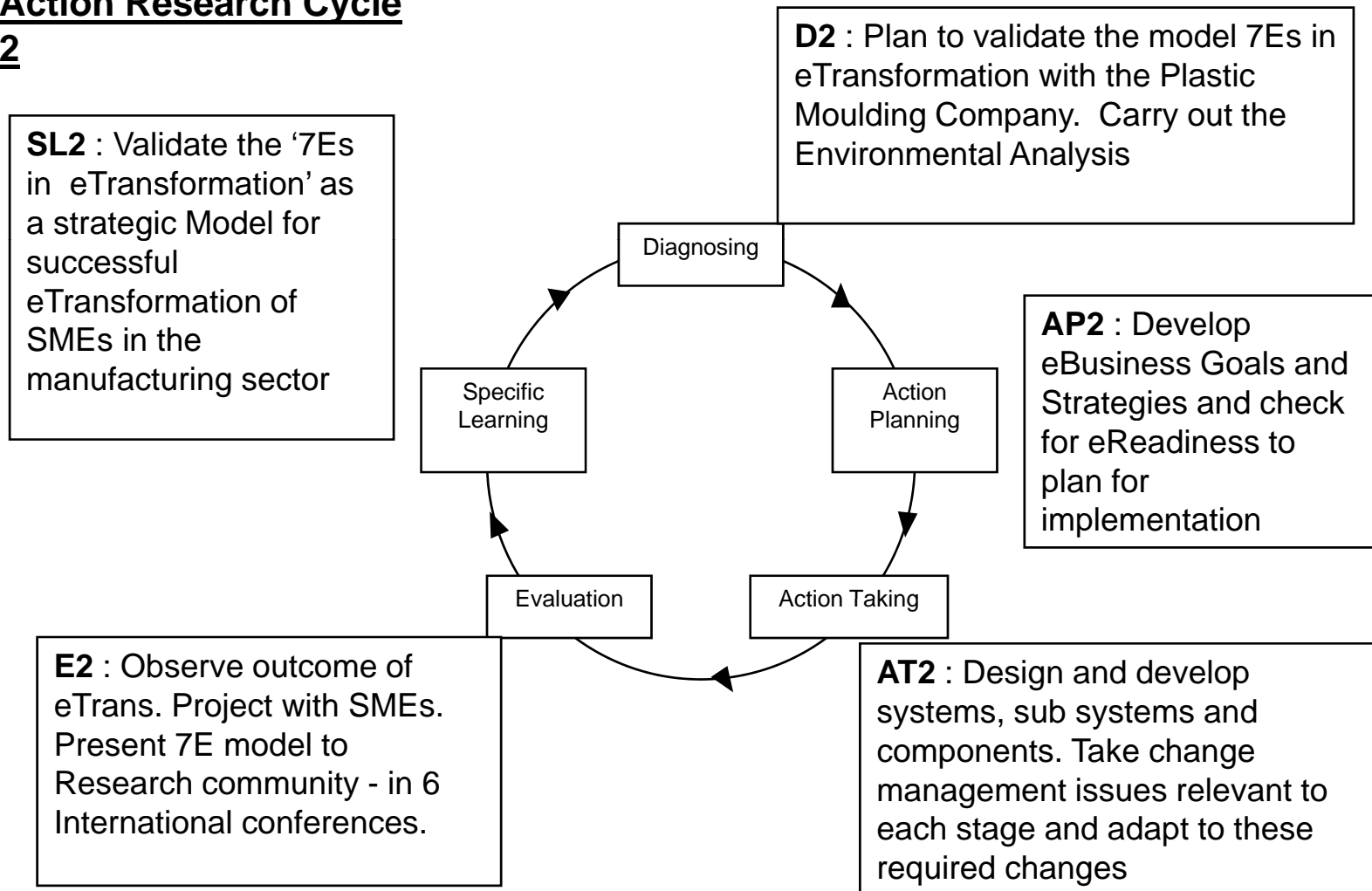


## Action Research Cycle 1



# Action Research Cycle 2

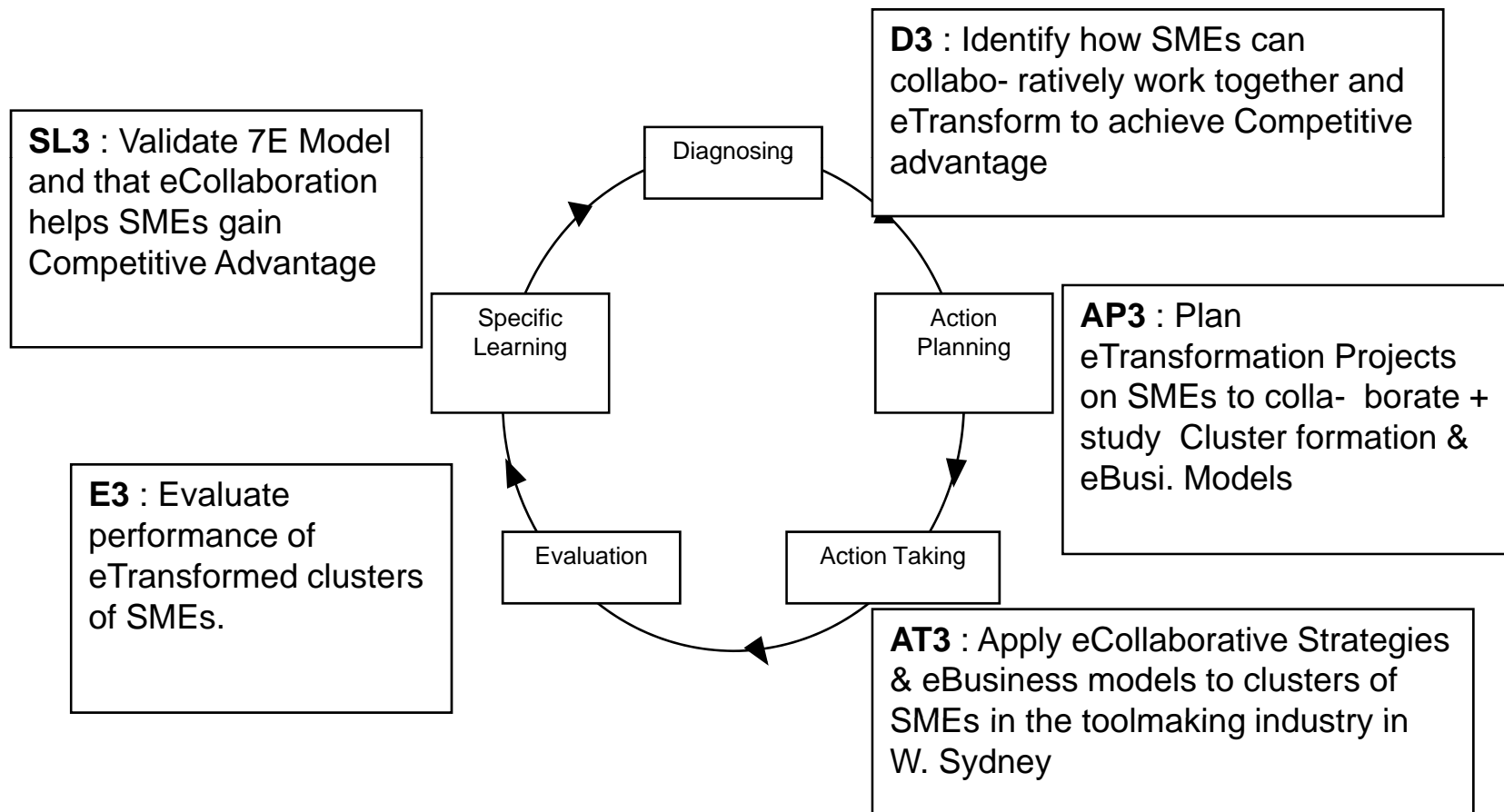
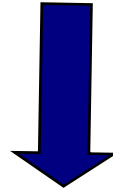
## Action Research Cycle 2





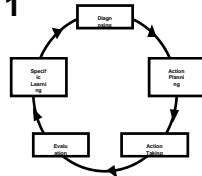
# Action Research Cycle 3

## Action Research Cycle 3



# Overall Process

## AR Cycle 1

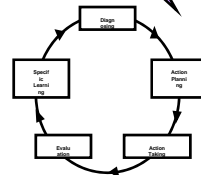


### Major Outcomes of AR cycle 1:

Understanding the Importance of eTransformation  
Identifying Important Facts of eTransformation

Search for a Strategic eTransformation Model  
Develop the 7E Model to be a comprehensive strategic eTransformation Model

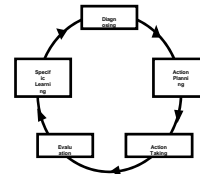
## AR Cycle 2



### Major Outcomes of AR cycle 2:

Validating the 7E Model by applying it to an SME

## AR Cycle 3



### Major Outcomes of AR cycle 3:

eCollaboration and the applicability of the 7E Model to a cluster of SMEs

# Overall Outcomes



| AR Cycle          | Data Gathering Technique   | Major outcome of each AR Cycle  | Contribution to Businesses (Projects)   |
|-------------------|--|---|---|
| <b>AR Cycle 1</b> | Literature Review,<br>Industry survey,<br>Interviews, Observations,<br>Questionnaire.                | Identifying importance of<br>eTransformation.<br>Important Aspects of<br>eTransformation.                 | Garment Industry Study in Sri Lanka   |
| <b>AR Cycle 2</b> | Literature Review,<br>Project Management,<br>Interviews,<br>Discussions,<br>Observations, Workshops. | Development of the Seven Es in<br>eTransformation<br>– A Strategic eTransformation<br>Model for SMEs      | eTransformation of the Plastic<br>Moulding Company in<br>Western Sydney.            |
| <b>AR Cycle 3</b> | Literature Review,<br>Industry study,<br>Interviews,<br>Observations, Questionnaire,<br>Seminars.    | Recognising eCollaboration as a<br>strategy for SMEs.<br>7E Model as a tool for<br>eCollaboration of SMEs | A Cluster Project with four<br>toolmaking companies in<br>Western Sydney, Australia |

- In this section, we outline the organization of the rest of the thesis and the contribution of each chapter towards the **final goal of combining data in order to benefit from the effectiveness of the visual content analysis of images and efficiency of the annotation based search for building an index structure for image databases.**

# Thesis Contents



- 1 Introduction and Motivation
- 2 Review of Related Work
- 3 Design and Development of Text-Based Image Retrieval System
  - 3.1 Design of Text-Based Image Retrieval System
  - 3.2 Development of Text-Based Image Retrieval System
  - 3.3 Summary
- 4 Extracting Semantics from Images
  - 4.1 Semantic Classification of Images
  - 4.2 Image Features
  - 4.3 Correcting Some of the Misclassified Images
  - 4.4 Summary
- 5 System Development and Experiment Design and Setup for its Evaluation
  - 5.1 The Architectural Framework
  - 5.2 Integration of Semantics and Visual Features
  - 5.3 Experimental Design and Setup
  - 5.4 Summary
- 6 Evaluation of Image Retrieval System
  - 6.1 Retrieval Efficiency
  - 6.2 Retrieval Accuracy
  - 6.3 Comparative Evaluation with Web Image Search Engines
  - 6.4 Summary
- 7 Conclusions and Future Work
  - 7.1 Research Summary
  - 7.2 Contributions
  - 7.3 Future Research
  - 7.4 Conclusion
- References

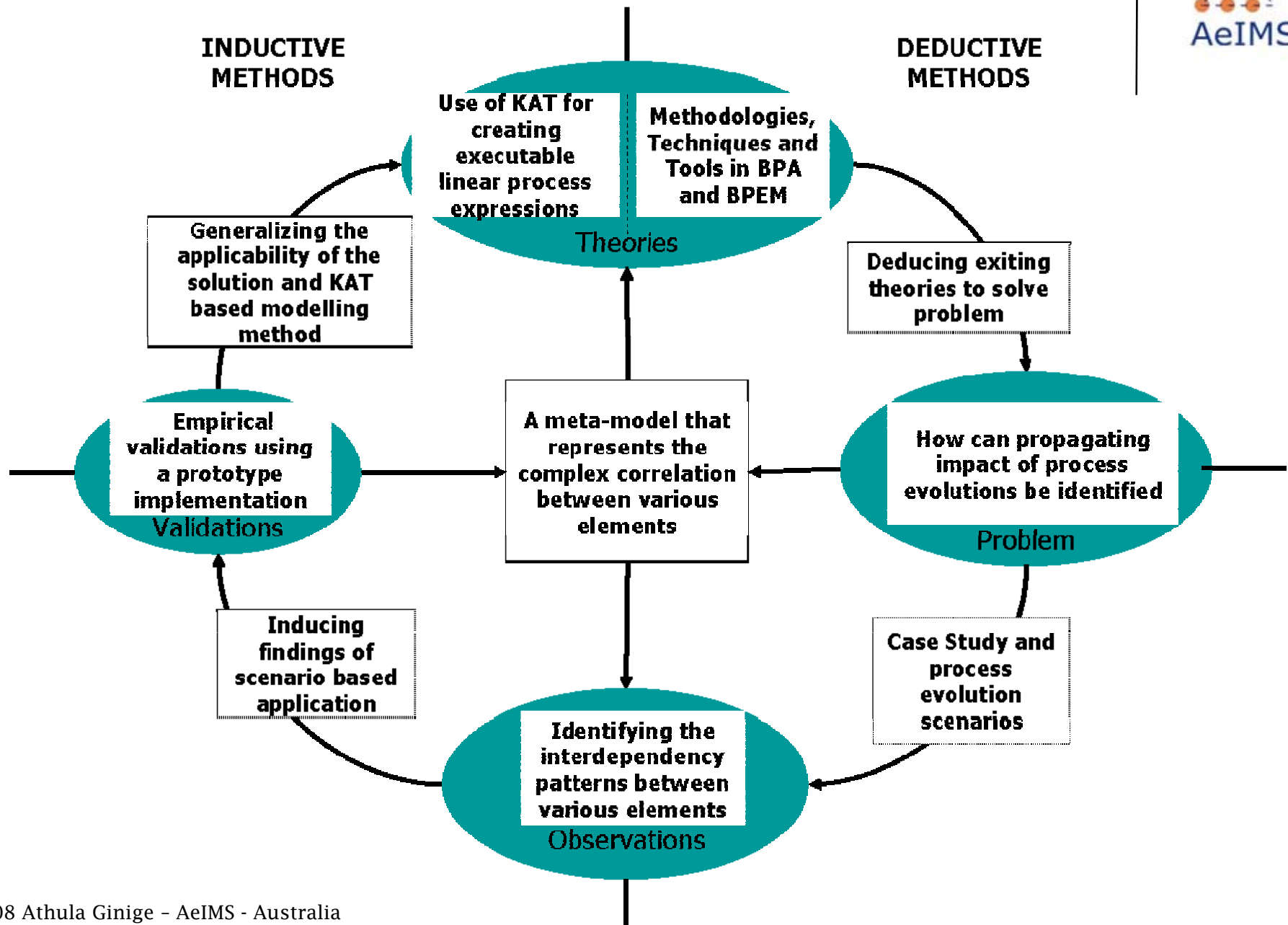
- The specific research question, for which answers are sought is “**How can organisations, accurately and effectively manage business process evolutions and changes in web-based workflows?** To answer this question, the divide-and-conquer approach is used, by formulating three sub-research questions as follows:
  - *What is the nature of correlations among and across elements of the four levels (pragmatic, semantic, syntactic, and implementation) of the paradigm of process automation - PoPA framework?*
  - *Where can changes and evolutions originate and what is the nature (or taxonomy) of process element changes?*
  - *Based on the answers to the above two questions, how can the propagating impact of evolutions and changes be identified prior to altering the process models or implemented workflow systems?*

# Overall Research Methodology

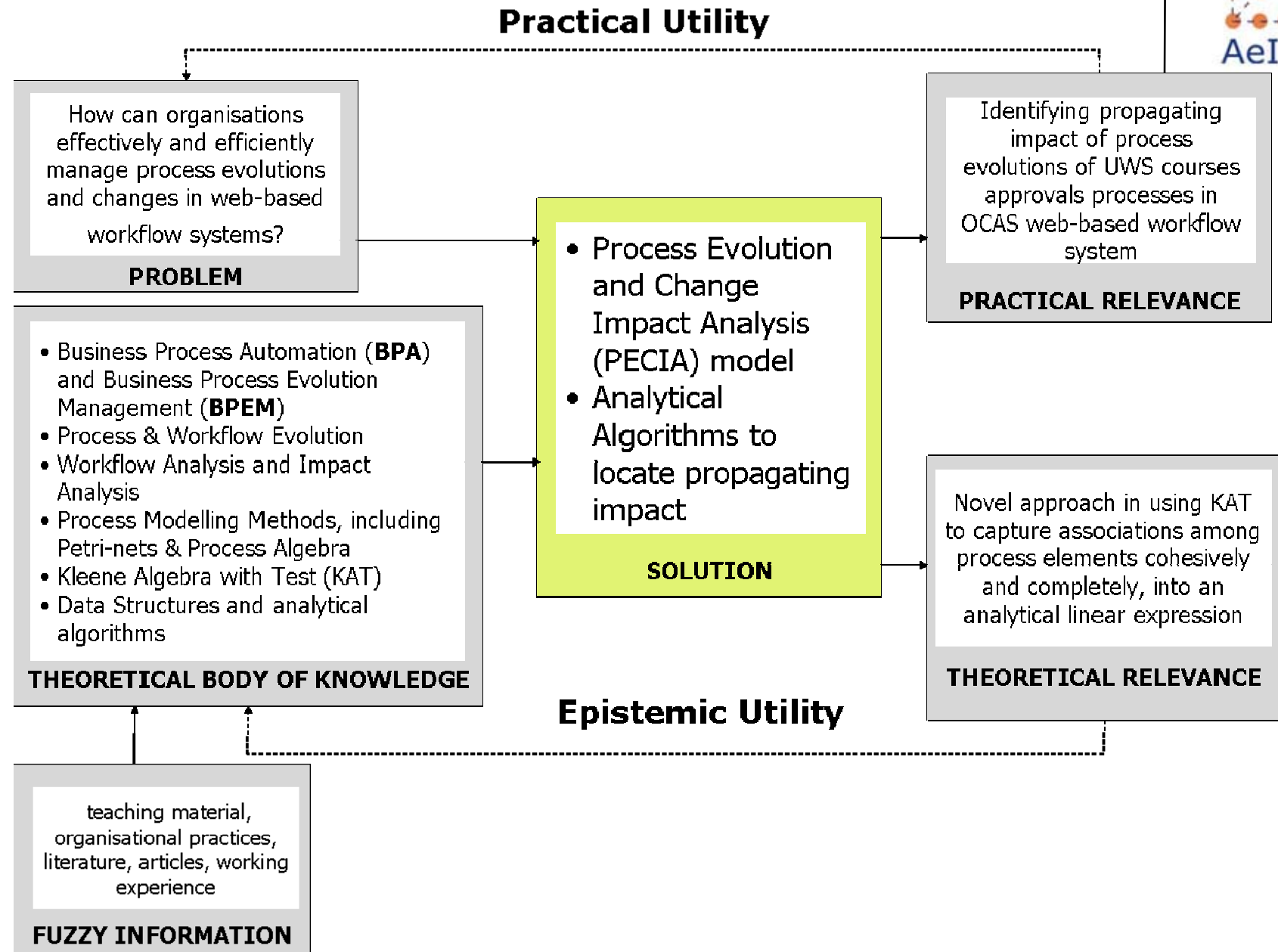


- The core work of this research can be mapped to the steps in the constructive research method, as it is more methodical and appropriate for this research. The steps in constructive research are:
- Detecting and defining a **problem**;
- Investigating the existing **theoretical body of knowledge** to deduce that the problem is worth solving;
- Constructing a **solution**;
- Verifying that the solution to ensure that it solves the initially set problem - **practical relevance**; and
- Evaluating the newly discovered knowledge in order position it within the existing body of knowledge – **epistemic relevance**.

# Overall Process







# Research Methods in Computing

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